Development and Evaluation of High-Fiber Dough Meal with Dietary Glycemic Control and Antioxidant Capacities

ABSTRACT

*Regular intake of high-fiber diet reduces the incidence of cardiac diseases, boosts glycemic regulation, and improves gastrointestinal function. Flour blends were formulated by compositing flours from finger millet (FM), wild melon (WM), and eggplant (EP); utilizing optimal mixture design of response surface methodology (RSM), the following blends were obtained: 100% FM (Control); FM 80: WM 10: EP 10 (FWE3), FM 10: WM 80: EP 10 (FWE5), and FM 45: WM 45: EP 10 (FWE7). Flours and dough meals from the blends were evaluated for chemical compositions, antioxidant and dietary glycemic properties. The proximate composition of flour blends and dough meal exhibited considerable variation (p≤ 0.05). Phosphorus and iron were the primary macronutrient and micronutrient in the dough meal, but were more pronounced in FWE7. The Ca:P and Na:K ratios were ≤ 1. The "phytate:mineral" molar ratios of the dough meal suggested, the divalent minerals under study would be bioavailable upon consumption. Free-radical scavenging capacities and antioxidant activities of the flour blends and their dough meals revealed that the flour blends exhibited higher activities than the control (100%FM). However, the dough meals exhibited higher free-radical scavenging capacities and antioxidant activities than the flour blends, with FWE7 having the highest values. Similarly, FWE7 displayed maximum inhibitory activities against α-amylase and α-glucosidase, lowest glycemic index and medium glycemic load. The study therefore, established, the dough meals, particularly FWE7, has been capable of mitigating oxidative stress and regulating glycemic response.*

***Keyword:*** *antioxidant properties, chemical composition, dietary fiber, dough meal and glycemic index*

**1.0 INTRODUCTION**

The pervasiveness of low-fiber foods has caused major health issues, because they significantly promote the growing consequences of chronic diseases.  However, proper intake of dietary fiber (DF) can diminish the likelihood of acquiring conditions such as hypercholesterolemia, cardiovascular disease, colorectal cancer, and diabetes mellitus. Dietary fiber constitutes the consumable portion of plants that remains undigested and unabsorbed in the small intestine, yet is metabolized by bacteria in the large intestine [1]. The health benefits of plant-based diets are ascribed to bioactive constituents like phytochemicals, antioxidants, and dietary fibers [2, 3]. Increased consumption of antioxidant dietary fiber, advances reduction of individual’s vulnerability to diseases like, diabetes, hypertension / cardiovascular diseases, obesity, colon cancer etc. These factors contribute to the rising trend of adopting high-fiber diets [4, 5]. Cereal grains, especially millets, are abundant in fiber, extraordinarily rich in phytochemicals and minerals, and contribute to the maintenance of the body's pH equilibrium. Millets possess numerous acknowledged health advantages attributable to their robust mineral and vitamin composition, alongside a low glycemic index, dietary calorie, and fat content.

Finger millet (Eleusine coracana), commonly referred to as tamba, serves as a fundamental cereal grain in certain low-income regions [6]. It is gluten-free, non-acid-forming [7], easily digestible, and characterized by a low glycemic index [8]. Its low glycemic index renders it an appropriate option for individuals with celiac disease and diabetes [8], as it is rich in carbs, dietary fiber, important amino acids, and vital minerals [8].

Cucumeropsis mannii, commonly referred to as wild melon, is a member of the Cucurbitaceae family [9]. It is a climbing plant that thrives in humid, wet climates, predominantly in the eastern and southern regions of Nigeria, where it is cultivated for its oil and dietary proteins [9]. It is available in both shelled and unshelled varieties in West African markets and is extensively utilized in West African cuisine [10]. In English, it is referred to as white melon, but in Yoruba, it is called ‘egusi-itoo’ [9]. The shelled seeds may be ground or milled both prior to and following roasting, serving as ingredients in soups and as condiments, as well as in other delicacies in Nigeria, including breakfast dishes and snacks, either as whole toasted seeds or as fried cakes made from milled seeds [11]. It is rich in antioxidant such as lycopene which is linked to decreased risk of cancer, heart diseases and age-related eye disorder [11]. Apart from the aforementioned, the seed therefore, might be used in food formulations to reduce the burden on other food resources such as peanuts as well as soybeans.

Eggplant (Solanum melongena L) is a fundamental component of African heritage and cuisine. It is an agricultural product esteemed for its high fiber content, antioxidant properties, and low caloric value, which significantly contribute to combating diabetes and lipid peroxidation [12]. It is consumed nearly every day by both rural and urban households [13]. They have diverse nutritional and pharmacological attributes that render them a beneficial enhancement to diets. The previous research conducted by Yusuff et al. [14] indicates that heightened consumption of eggplant may reduce the risk of overall mortality, obesity, elevated blood glucose levels, and cardiovascular diseases.

Prior investigators had studied the nutritional composition and health benefits of finger millet, wild melon, and eggplant exclusively or composited with other flours (Mudau et al.,[15]; Chuyeh-Nforba, et al., [16]; Chamba, et al., [17]). However, considering the persistent demand for flour blends appropriate for the production high fiber dough meal, it is beneficial to examine the synergistic effects of these indigenous crops on glycemic control and antioxidant properties as it remains unexplored. This study therefore aims to provide information on the nutritional composition, glycemic control and antioxidant capacities of the flour blends and dough meals developed from the combinations

**2.0 MATERIALS AND METHOD**

**2.1 Sources of Food Materials**

The basic materials, finger millet (*Eleusine coracana*), were procured at the “Gwagwalada” market in Abuja, Nigeria. Wild Melon (*Cucumeropsi mannii*) was acquired at the "Ikole" market in Ekiti State, Nigeria. Eggplant, characterized by its purple hue, or Brinji (*Solanum macrocarpon*), was procured at the "Erekesan" market in Akure, Ondo State, Nigeria.

All reagents used were of analytical grade and purchased from a renowned chemical store, in Akure, Ondo State, Nigeria.

**2.1.1 Processing of Finger Millet Flour Samples**

Finger millet was converted into flour using the method outlined by Ramashia et al. [8] with minor modifications. Fifteen kilograms (15kg) of finger millet grains were winnowed, rinsed in clean water, soaked for eight hours, drained, and dried before being processed with a hammer mill (Number 3100, Huddinge, Sweden) and sieved to produce finger millet flour. Enclose in a zip-lock polyethylene bag and maintain at a temperature of 4°C before use (fig 1).

Finger millet grains

↓

Sort

↓

Washing

↓

Soaking (6 hours)

↓

Drying

↓

Milling (hammer mill)

↓

Sieving

↓

Finger millet flour

**Figure 1: Flow Chart showing the preparation of Finger Millet flour**

**Source: Ramashia et al. (2018)**

**2.1.2 Processing of Wild Melon Flour**

Wild melon was converted into flour using the method outlined by Mehra et al. [9]. Ten kilograms (10kg) of wild melon samples were fried at 60°C for 20 minutes, thereafter de-husked, screened, sun-dried, and ground using a hammer mill (Falling Number 3100, Huddinge, Sweden). The wild melon was defatted with N-Hexane for 8 hours, and the resulting flours were dried (using a cabinet dryer at 60°C and allowed to cool at ambient temperature) before being grinded into flour. Packaged in sealed polythene zip lock bags, and stored at a temperature of 4°C before to use (fig 2).

Matured wild melon

Frying (60oC for 20 minutes)

Dehusking

Milling

Defatted (Using N-Hexane)

Drying (Cabinet dryer at 600 C)

Grinded into flour



Defatted wild melon flour

## Fig 2: Flow Chart showing the preparation of wild melon flour

## Source: Mehra et al., (9)

**2.1.3 Processing of Eggplant Flour**

The method of Uthumporn et al. [18] was utilized with minor modifications; fresh eggplants were rinsed with tap water to eliminate all soil and extraneous material. The eggplants, together with their skins, were cut into thin slices. The sliced eggplants were dehydrated using an air dryer (AFOS Limited, Kingston upon Hull, United Kingdom) at 40°C for 72 hours. Dried eggplants were processed using a Stainless Steel Vertical Type High-Speed Grinding and Pulverizing Machine (Model RT-34, WHL Machinery, Selangor, Malaysia) and subsequently sieved using a 500 mesh sieve. The eggplant flour was stored in a zip-lock polypropylene bag at 4°C prior to usage (Fig 3).

Eggplant

↓

Washing

↓

Cut/slice

↓

Drying (carbinet dryer at 400C for 72 hours)

↓

Milling (harmer mill)

↓

Sieving

↓

Eggplant flour

Fig 3: Flow Chart showing the preparation of Eggplant Flour

Source: Uthumporn *et al*., (18)

Dough meal Flour Blend Formulation

Mixture design of response surface methodology (RSM) was used for optimizing the flour blends. Ten (10) experimental runs were obtained as seen on Table 1. The flour blends were optimized for health benefits, aiming at a high *in – vitro* antioxidant activity of greater than (>70).

Table 1. Response surface (optimal mixture design) experimental runs of finger millet, wild melon and eggplant flour blends

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  | **Antioxidant Properties** | |
| **Runs** | **Finger millet (%)** | **Wild melon (%)** | **Eggplant (%)** | **Fe2+ chelation**  (mg/mL) | Nitric oxide mgGAE/g |
| **1** | **10.00** | **10.00** | **80.00** | 67.76±6.92d | 32.57±5.70i |
| **2** | **45.00** | **10.00** | **45.00** | 64.57±1.58e | 64.55±0.20f |
| **3** | **80.00** | **10.00** | **10.00** | 80.32±7.72b | 84.54±1.00b |
| **4** | **56.667** | **21.667** | **21.667** | 57.16±3.60g | 69.82±0.71d |
| **5** | **10.00** | **80.00** | **10.00** | 88.56±2.88a | 79.96±0.71c |
| **6** | **80.00** | **10.00** | **10.00** | 62.81±6.40f | 39.46±0.57h |
| **7** | **21.667** | **21.667** | **56.667** | 77.91±2.94c | 86.64±0.48a |
| **8** | **45.00** | **45.00** | **10.00** | 67.70±7.97d | 63.58±0.76f |
| **9** | **33.33** | **33.33** | **33.33** | 54.83±2.80~~h~~ | 65.85±1.28e |
| **10** | **10.00** | **80.00** | **10.00** | 61.76±7.65f | 55.93±0.42g |

**2.2 Assessment of proximate composition and energy value of flour blends and dough meal**

The proximate components (moisture, total ash, crude fiber, and crude protein, fat) of the extruded breakfast were assessed in accordance with the Association of Official Analytical Chemists [19]. Carbohydrate was derived by subtraction, as follows:

Carbohydrate (%)= 100 - (% moisture +% crude protein + % crude fiber+%fat+% ash ….Equ (1)

The energy value was determined using the Atwater factor method: [(9×crude fat) + (4×crude protein) + (4×carbohydrate)]. …………………………………………………………. Equ (2)

**2.3 Assessment of Specific Mineral Composition**   
The potassium, magnesium, calcium, sodium, phosphorus, manganese, copper, and iron content were analyzed according to AOAC (19) methodology.   
**2.4 Quantitative Analysis of Phytochemical Components in Dough Meal**

The alkaloids, saponins, tannins, phytate, oxalate, and the trypsin inhibition approach delineated by Eze and Kanu [20]

**2.5 In-vitro antioxidant analysis of the aqueous extracts from the designed flour mix dough meal samples**

The *in-vitro* antioxidant activity of the aqueous extracts from the meal sample was assessed using standardized techniques. The free radical scavenging activity of the food samples was assessed using Ferric-reducing antioxidant activity (FRAP) as per Zhang and Lin [7].The total phenol free radical scavenging capacity was assessed by Adefega et al. [21]. The free radical scavenging activity of 2,2-diphenyl-1-picrylhydrazyl (DPPH) was assessed according to the methodology outlined by Aluko and Monu [22]. The chelating activity of iron Fe2+ in the aqueous extract of the prepared food was assessed using the method established by Xie et al. [23]. The nitric oxide radical scavenging activity of the meal extract was assessed using the method described by Girgih et al. [24].

2**.6 Assessment of the Inhibitory Effects of α-Amylase and α-Glucosidase on Dough Meal**Levels of α-amylase and α-glucosidase were evaluated using the methodologies outlined by Sheikh et al. [25] and Kumar et al. [26].

**2.7 Assessment of Glycemic Index Analysis**

The glycemic index was obtained by method ascribed by Wolever et al [27]. The glycemic load (GL) was determined by multiplying the carbohydrate content of each dough meal sample in a standard serving by its glycemic index (GI) value [28], as illustrated below:

GL = Net carbohydrate (g) x GI ……………………… Equ (3)

100

Net carbohydrate = Total carbohydrates in the food sample

**2.8 Dietary Fiber Analysis**

Soluble dietary fiber (SDF) and insoluble dietary fiber were analyzed according to the AOAC [19] method.

2.9 Data Analyses

Data from triplicate readings were analyzed, and results were presented as mean ± standard deviation. One-way analysis of variance was employed to evaluate the means. Significant differences between means were identified using Duncan's test, with a significance level set at (p≤0.05).

**3.0 RESULT AND DISCUSSION**

**3.1 Proximate Composition (%) of Flour Blends and Dough Meal (dry basis)**

The moisture level of flour exhibited substantial variation (p<0.05) among samples. The moisture level of flour mixtures varied between 3.40% and 5.26%. FWE5 demonstrated a minimum value, whilst FWE3 revealed a maximum value. The dough meal varied from 16.69% in FWE5 to 20.74% in FM, whereas the moisture content of the flour blends adhered to the acceptable moisture levels (> 10%) for flour as per WHO [29]. The reduced moisture content identified in this investigation suggests that the flour may demonstrate enhanced shelf durability. Fatoumata et al. [30]; Gaikwad, [31], noted that low moisture level in food is crucial for storage, since it can inhibit the growth of bacteria, fermentation, and caking. The moisture level of dough meal was higher than that of the flour blends, this might be attributed to the addition of water that is necessitated during the meal's production, thus suggesting a short shelf life stability for the dough meal[29, 31].

**Table 2: Proximate Composition (%) of Flour Blends and Dough Meal (dry basis)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sample | Moisture Content | Crude Ash | Crude Fibre | Crude Fat | Crude Protein | Carbohydrate | Energy value Kcal |
| **FLOUR BLENDS** | | | | | | | |
| FM | 4.12±0.02b | 3.17±0.02b | 2.70±0.01d | 1.82±0.02d | 14.92±0.04d | 73.11±0.10a | 376.50 |
| FWE3  **80:10:10** | 5.26±0.02a | 3.22±0.02a | 7.05±0.01c | 6.99±0.01c | 37.43±0.04ab | 43.05±0.00f | 384.83 |
| FWE5  **10:10:80** | 3.40±0.30c | 3.05±0.00d | 8.98±0.00a | 7.30±0.00ab | 40.76±0.00a | 36.51±0.10h | 374.78 |
| FWE7  **45:45:10** | 5.06±0.06a | 3.12±0.02c | 8.03±0.01b | 5.89±0.01c | 40.68±0.02a | 37.22±0.06f | 364.61 |
| Ref | <10 | <3.00 | <5.0 | 10-25 | >16 | 64 | 344.00 |
| **DOUGH MEAL** | | | | | | | |
| FM  100 | 20.74±0.04a | 2.53±0.03a | 3.67±0.01d | 1.99±0.01d | 10.46±0.02d | 60.71±0.09a | 320.59 |
| FWE3  **80:10:10** | 17.20±0.10b | 2.60±0.01b | 4.74±0.00c | 3.86±0.00c | 17.20±0.00c | 54.38±0.09a | 321.06 |
| FWE5  **10:10:80** | 16.69±0.01d | 2.25±0.01b | 3.89±0.01b | 6.71±0.01b | 19.45±0.04b | 50.49±0.08b | 340.15 |
| FWE7  **45:45:10** | 19.30±0.10c | 1.07±0.25a | 5.20±0.00a | 7.35±0.05a | 22.05±0.03a | 45.02±0.10c | 334.43 |

*Mean ± standard deviation of three replicate; with the same superscript letter within the same column differ significantly (P< 0.05*)

FM=Finger Millet 100% (CONTROL), FWE3= Finger millet 80%, Wild melon 10%, Eggplant 10%, FWE5= Finger millet 10%, Wild melon 80%, Eggplant 10%, FWE7= Finger millet 45%, Wild melon 45%, Eggplant 10%.

The crude ash level of the flour blends varied from 3.05% (FWE5) to 3.22% (FWE3), while for dough meal, the crude ash content varied from 1.07% (FWE5) to 2.60% (FWE3). The lower ash content observed in dough meal compared to the flour blends might be attributed to the burning off of the volatile components, during heating. Similarly, the reduction might, possibly be attributed to the alteration in the varieties and quantities of minerals available in the ash, due to processing (Kukuruzović et al., [32]). The ash content refers to the inorganic, non-combustible residue remaining after the food is entirely burned, it principally reflects the mineral content of the food [33, 34], and it is an indicator of the mineral content of the food.

 The crude fiber content of the flour blends varied from 2.70% to 8.98% (FWE5), whereas in dough meals, values varied from 3.67% in FM to 5.20% in FWE7. This suggests that the inclusion of wild melon and eggplant significantly contributed to the fiber content of flour and dough meal. High-fiber diets are considered to improve gastrointestinal system functions [35]. However, the value derived from dough meal is lower than values obtained from flour mixes. Heating, may not directly cause a reduction in fiber content but might alter the fiber structure in dough meal or possibly changing the balance between soluble and insoluble fiber fractions and impacting the digestibility and other properties (Maina *et al.,* [36].  Albeit the flour blends might likely provide 21-64% of fiber daily requirements while dough meals might provide 29 – 36% of the recommended daily fiber requirements of 14 g/kcal. Nevertheless, integrating the dough meal with other foods, such as vegetable soup, would enhance the intake of nutritional fiber. The high fiber content in composite flour will improve digestion and alleviate constipation linked to items made from refined grain flours [37, 38]. Recent research [39, 53] indicates that dietary fiber intake enhances glucose and lipid absorption in the small intestine, slows stomach emptying, sustains satiety levels, and contributes to reduced weight gain.

The crude fat of the flour blends varied from 1.82 (FM) to 7.30% (FWE5), while the dough meal content varied from 1.99 (FM) to 7.35% (FWE7). It is lower than values reported for flour blend comprising of sorghum, pigeon peas, eggplants, and pumpkin seeds (16.16 - 20.26%) as reported by Chamba, et al (2024) [17]. Fat is a crucial component utilized to enhance energy density in the formulation of fortified blended foods for populations, that are at risk. Higher fat contents were observed in the flour blends than the control (FM). This may be attributed to the contribution of the wild melon (Cucumeropsis mannii) as the fat in eggplant is negligible. Enujiugha et al., [40] reported wild melon to be a good source of fat with values ranging from 25.56 – 55.0%. Unsaturated fatty acids have been reported to be the major fatty acids in wild melon (Olofinnade et al., [41]. Unsaturated fatty acids are crucial in cardiac health, cognitive function and inflammation control, they also act as energy sources. It is noteworthy, that the fat content of both the flour and dough meal are within the recommended value (10- 15%) by WHO [29], suggesting the flour and dough can exhibit enhanced shelf stability consequent to reduced fat oxidation.

The protein content in flour blends varied between 14.92 (FM) and 40.76% (FWE5), for the dough meal protein value ranged from 10.46 (FM) to 22.05% (FWE7). No significant difference (p≥ 0.05) was observed in the protein content of FWE5 and FWE7 in flour blends. The high protein contents might be attributed to the quantity of wild melon added, since it is a good source of protein (Enujiugha et al., [40]. The protein level obtained exceeds values (6.17 -14.96%) reported by Chamba, et al [17] for composite flour of sorghum, pigeon peas, eggplants, and pumpkin seeds. Also, the protein values, fairly compares to values reported by Fatoumata et al. [30], who reported a protein value of 18.09 – 25.12% in the supplementation of millet with cowpea and Bambara groundnut mixtures. The formulation of dough meal resulted in about 30 – 54% decrease in the protein content of the flour, which may be attributed to protein denaturation during cooking. Interestingly, values obtained exceeds the daily protein requirement for children aged 3 to 7 years, which varies from 13 to 26 grams per day [40], the flour blends might likely provide 57 – 157% of children daily requirements while the dough meal might provide 40 – 85% of the daily protein requirement.

The carbohydrate content of the flour blends varied from 36.51 (FWE5) to 73.11% (FM). In the dough meal, the carbohydrate ranged between 45.02 (FWE7) and 60.71% (FM). The disparity in carbohydrate content of FM (100%) and composite flour may result from variations in the levels of other constituents (wild melon and eggplant), which are not rich sources of carbohydrate, resulting in minimal carb content of flour blends/doughs compared to FM. Reducing carbohydrates in diets can help lower blood sugar levels, improve insulin sensitivity, and promote weight loss [41]. Furthermore, the variation observed in the carbohydrate observed in the flour and the dough might be attributed to gelatinization, which is capable of altering the structure and properties of the starch (Donmez et al., [42]

Energy content of flour blends varies from 364.61 (FWE7) to 384 kcal in FWE3 (flour), whereas dough meal ranges from 320.59 (FM) to 340.15 kcal in FWE5. FWE3 and FWE5 had the highest energy content in both the flour and dough, however, these values are significantly lower than the recommended dietary allowance for energy consumption in adults [34]. It implies therefore that the flour and the dough might generates fewer calories in comparison to the 2200 – 2800 kcal recommended dietary allowance for energy consumption in adults [34]. The low energy values obtained implies that the flour as well as the dough might be an excellent diet for weight management as it permits individuals to consume greater portions of the food while still ingesting less calories, enhances feeling of satiety and influences appetite.

**3.2 Mineral and phytonutrient contents (Mg/100g) and molar ratios of dough meal derived from blends of finger millet, wild melon, and eggplant flour**   
Table 3 presents the mineral and phytonutrient composition, as well as the molar ratio, of the dough meal. The mineral richness of FWE7 surpasses that of other samples, particularly FM, which has the lowest mineral content. This, however, signifies that FWE7 which comprises of 45% finger millet, 45% wild melon, and 10% eggplant is a preeminent supplier of minerals for the body compared to others. The high mineral concentration in FWE7 demonstrates its ability to maintain normal cellular homeostasis and regulate fluid, electrolyte, and blood pressure balance in the body as reported by Donmez et al. [42]. The most elevated concentrations of Na, K, Ca, P, Mg, Fe, and Zn as seen in FWE7 may be ascribed to the incorporation of wild melon and eggplant. The most predominant mineral in the dough meal is phosphorus (P) followed by calcium (Ca). Phosphorus is important for bone and teeth health, energy production, and cell function, plays a decisive role in DNA and RNA synthesis, and helps the body utilize other vitamins and minerals. Correspondingly, calcium is also essential for building and maintaining healthy bones and teeth. The Ca/p ratio varied from 0.18 in FWE7 to 0.24 in FM, . Donmez et al. [42] indicated that a Ca/p ratio exceeding 1 is optimal [42, 43], whereas lower ratios may lead to detrimental health effects, including arterial calcification, bone loss. Na/K ratio ranged from 0.72(FWE5) – 0.95 (FM), Na/K ratio of ≤ 1 may be connected with a clinically pertinent decrease in the risk of stroke and denotes a likely target for health interventions (Mosallanezhad et al., 2023[43]). The data obtained especially for Na/K remained within the range identified by [44]. Consequently, the reduced ratio identified in this study may confer a benefit to hypertension individuals.

**Table 3:** **Mineral, phytonutrient compositions (Mg/100g) and molar ratio of dough meal from blends of finger millet wild melon and eggplant flour**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SAMPLE | **FM**  **100** | **FWE3**  **80:10:10** | **FWE5**  **10:10:80** | **FWE7**  **45:45:10** |
| Sodium (Na) | 12.70±0.01d | 13.00±0.04c | 15.70±0.01b | 18.10±0.02a |
| Potassium (K) | 13.30±0.03d | 17.70±0.01c | 21.70±0.02b | 31.50±0.01a |
| Calcium (Ca) | 96.80±0.02d | 108.80±0.05c | 120.40±0.02b | 123.60±0.05a |
| Phosphorus (P) | 406.30±0.05d | 526.40±0.03c | 602.40±0.05b | 684.60±0.10a |
| Magnesium (Mg) | 36.40±0.05d | 41.20±0.02c | 45.00±0.01b | 47.20±0.02a |
| Iron (Fe) | 16.47±0.01d | 19.87±0.02c | 22.17±0.05b | 27.77±0.01a |
| Manganese (Mn) | 15.90±0.01c | 18.20±0.02b | 19.50 ±0.01a | 11.40±0.01d |
| Zinc (Zn) | 2.02±0.01d | 2.45±0.00c | 4.02±0.01b | 6.98±0.01a |
| Copper (Cu)  Ca/P | 1.23±0.01b  0.24 | 1.88±0.01b  0.21 | 2.10±0.01a  0.20 | 0.88±0.01c  0.18 |
| Na/K | 0.95 | 0.76 | 0.72 | 0.88 |
| Phytate (mg/100g) | 20.18±0.03c | 23.20±0.07b | 16.12±0.00d | 28.13±0.06a |
| Oxalate (mg/100g) | 32.17±0.10d | 44.12±0.03b | 35.33±0.12c | 47.79±0.14a |
| Tannin (mg/100g) | 7.23±0.02b | 6.23±0.03d | 10.33±0.01a | 9.21±0.02c |
| Alkaloid % | 1.22±0.01d | 1.18±0.01c | 1.98±0.00b | 2.30±0.01a |
| Saponin(mg/100g) | 33.40±0.30c | 31.21±0.10d | 40.24±0.20a | 38.41±0.10b |
| Trypsin inhibitor (mg/100g) | 1.11±0.00d | 2.22±0.00c | 3.33±0.00b | 4.44±0.00a |
| Phytate/Calcium | 0.20 | 0.21 | 0.13 | 0.23 |
| Phytate/zinc | 9.98 | 9.46 | 4.01 | 4.03 |
| Phytate/Iron | 0.28 | 0.45 | 0.71 | 1.01` |

*Mean ± standard deviation of three replicate; with the same superscript letter within the same column differ significantly (P< 0.05*)

Key: FM=Finger Millet 100% (CONTROL), FWE3= Finger millet 80%, Wild melon 10%, Eggplant 10%, FWE5= Finger millet 10%, Wild melon 80%, Eggplant 10%, FWE7= Finger millet 45%, Wild melon 45%, Eggplant 10%, Ca/P= Calcium: Phosphorus Na/K= Sodium: potassium

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The phytate concentration in the sample varied from 16.12 mg/100g in FWE5 to 28.1 mg/100g in FWE7. The elevated phytate level in FWE7 may be attributed to the addition of wild melon, which could have contributed to the increased phytate content in the meal. Increased concentrations of anti-nutrients, such as oxalate, saponin, and phytate, can chelate calcium, magnesium, iron, and zinc, so rendering them inaccessible by forming complexes; the value obtained surpasses that of [7], which indicates a low phytate level (5.12 – 10.13mg/100g) in multigrain porridge. A different researcher documented a low phytate concentration (7.9 mg/100 g) in amaranth grain Soliman, [44]. Consequently, phytate significantly diminishes mineral bioavailability; hence, a low phytate concentration in diet indicates that most minerals present will be accessible for absorption. The value of 28.13 mg/100g for FWE7 is within the recommended daily intake range of 0.18 to 4.57 g/day Alemayehu et al., [45]. Saponins have several health benefits, including immunostimulatory, hypocholesterolemic, anticancer, anti-inflammatory, and antibacterial properties. High consumption of saponin in food can aid in lowering cholesterol levels and decreasing the prevalence of obesity-related disorders. Trypsin inhibition varied from 1.11 mg/100g in 100% finger millet to 4.44 mg/100g in FWE7.

The phytate/calcium ratio varied from 0.13 in FWE5 to 0.23 in FWE7. The phytate/calcium ratio indicates the bioavailability of minerals, specifically calcium, in the body. The current results demonstrate that FWE7 can bind a greater amount of calcium for the production of bones and teeth. The phytate/zinc ratio varied from 4.01 in FWE5 to 9.98 in FM. The phytate/zinc ratio in FM was significantly elevated (9.98), indicating that FM possesses a greater capacity to bind zinc, hence enhancing its bioavailability for the body compared to other sources. These results indicate that the use of this product will aid in diminishing the prevalence of zinc insufficiency in the body. The phytate/iron ratio varied from 0.28 in FM to 1.01 in FWE7. The phytate/iron ratio was significantly elevated in sample FWE7, indicating that FWE7 possesses a greater capacity to bind iron, hence enhancing its bioavailability for the body compared to others. The low content of anti-nutrients in food is significant from a health perspective. According to Olagunju [7], anti-nutrients can attach to nutrients (proteins, minerals), so obstructing their absorption and use, which ultimately diminishes the nutritional value of the diet [7]. The anti-nutrient levels in the formulated meal were markedly elevated compared to those in whole finger millet; concurrently, finger millet has been documented to possess lower anti-nutrient content than wild melon and eggplant [45, 46].

3.4 *In-vitro* antioxidant scavenging capacities on flour blends and dough meal

Antioxidants are chemical substances that can prevent the oxidation of cellular components, hence averting oxidative stress in the body. The antioxidant activities of flour blends and dough meal derived from the combinations of finger millet, wild melon, and eggplant are illustrated in Figure 4 below. The antioxidant scavenging capacity of the flour (F) against FRAP, phenolic compounds, DPPH, Fe2+ chelation, and nitric oxide (NO\*) and dough meal (D) was concentration-dependent. The results indicated that the flour exhibited decreased activity in FRAP and total phenolic content, except for DPPH, Fe2+ chelation, and NO\*. All the flour blends exhibited higher antioxidant and scavenging abilities than FM, this ability might be attributed to the presence of various phytochemicals in the wild melon and eggplant, such as flavonoids, phenolic acids, and carotenoids, which act as powerful antioxidants by scavenging free radicals and reducing oxidative stress.

The capacity of dough meal to neutralize free radicals in relation to Ferric lowering antioxidant power FRAP varied from 50.87 in FMD to 98.23 mgAAE/g in FWE7D; phenolic content ranged from 6.27 in FWE7 to 8.44 mgAAE/g in FMD; DPPH inhibition was between 54.64 in FWE5D and 73.07% in FEW7D; Fe2+ chelation ranged from 68.97 in FWE5D to 84.85 mg/ml in FEW7D; and NO\* levels varied from 63.07 mg/100g in FEW5D to 91.17 mg/100g in FEW7D. Heat during cooking enhanced scavenging capability of dough meal compared to flour; hence, FEW7D possesses a significant capacity to neutralize free radicals that might induce oxidative stress in the body than the flour. This outcome align with the findings of Oluwajuyitan et al. [3] regarding the antioxidant activity of Plantain-based dough meal. Consequently, antioxidants can neutralize free radicals, chelate metal catalysts, activate antioxidant enzymes, diminish α-tocopherol radicals, and inhibit oxidase. The formulated sample, particularly FWE7, exhibits appropriate antioxidant properties; consistent consumption may augment endogenous antioxidant activity to combat the excessive generation of free radicals in the body [54].

a b



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**Figure 4: *Invitro*-antioxidant scavenging abilities on flour blends and dough meals**

FMF=Finger Millet 100% (CONTROL) flour, FMD=Finger Millet 100% (CONTROL) dough meal, FWE3F= Finger millet 80%, Wild melon 10%, Eggplant 10% (flour), FWE3D= Finger millet 80%, Wild melon 10%, Eggplant 10% (dough meal), FWE5F= Finger millet 10%, Wild melon 80%, Eggplant 10% (flour), FWE5D= Finger millet 10%, Wild melon 80%, Eggplant 10% (dough meal), FWE7F= Finger millet 45%, Wild melon 45%, Eggplant 10% (flour). FWE7D= Finger millet 45%, Wild melon 45%, Eggplant 10% (dough meal).

The inhibition of α-Amylase and α-Glucosidase (%) activities of dough meal

Alpha-amylase and alpha-glucosidase are significant enzymes in the breakdown of carbohydrate; alpha-amylase breaks down starch into smaller sugars, and alpha-glucosidase further breaks these down into absorbable monosaccharides like glucose. Inhibiting these enzymes can help manage blood sugar levels and prevent postprandial hyperglycemia. The α-Amylase inhibition percentage on the dough meal (Figure 5) varied from 15.17% in FM to 28.33% in FWE7, similarly, the α–glycosidase inhibitory activities also varied from 25.32 in FWE3 to 44.59% in FWE7. Higher α-amylase and α–glycosidase inhibitions exhibited by FWE7 might be attributed to the presence of phenolic compounds as well as the dietary fiber introduced through the inclusion of wild melon and the eggplant. Cattivelli et al. [47] reported that phenolics in purple eggplant particularly hydroxycinnamic acid amides, can inhibit α-glucosidase and α-amylase. Phenolics are known for their antioxidant and potential anti-diabetic properties. Chen & Kang [48] also reported that phenolics in wild melon inhibits carbohydrate hydrolyzing enzymes.

In the same vein, dietary fiber from eggplant can impede the activities of both alpha-amylase and alpha-glucosidase, thus regulate blood glucose levels. Dietary fiber, particularly soluble fiber, can adsorb glucose and delay its diffusion, slowing down the absorption of carbohydrates into the bloodstream.  Purple egg plants are rich in both soluble and insoluble fiber (Hasan et al., [44]; Mohamed, et al., [55] which explains the reason for our observation. Our results corroborate the observation of Olugbuyi et al. [49], in dough meal derived from plantain and rice bran blends that elevated temperatures (heating) might also, generate resistant starch, which may contribute to increased inhibition in dough meal. Consequently, FWE7 exhibit the capacity to control type 2 diabetes mellitus by decreasing glucose uptake in the body.

a b

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## Figure 5. The α – Amylase and α – Glucosidase (%) of the dough meal from blends of finger millet wild melon and eggplant flour

## FM=Finger Millet 100% (CONTROL), FWE3= Finger millet 80%, Wild melon 10%, Eggplant 10%, FWE5= Finger millet 10%, Wild melon 80%, Eggplant 10%, FWE7= Finger millet 45%, Wild melon 45%, Eggplant 10%.

**3.7 Dietary fiber content of the dough meal**

The insoluble dietary fiber varied from 25.35 in FWE5 to 45.03 in FM, while the soluble dietary fiber varied between 10.65 (FWE5) and 15.44 in FWE7. Soluble fiber slows digestion and reduces the rate of glucose absorption after ingestion [49]. A diet abundant in insoluble dietary fiber is crucial, since it facilitates digestion, mitigates constipation, and may lower the risk of chronic diseases. The advised daily consumption of total dietary fiber is 25 to 30 grams [50]. Stephen et al. [51] observed that the accumulation of dietary fiber aids in body weight management and enhances overall metabolic function, including its effects on glucose and lipid homeostasis as well as insulin sensitivity.

IDF:SDF exhibits a reduced value in dough meal 2:1 relative to 100% finger millet 3:1, while the values align with the WHO norm of 2:1 suggested for a daily meal. This indicates that prepared dough meals are beneficial sources of dietary fiber for the body when comparing the IDF:SDF ratio of FM (3:1) to recommended WHO value (2:1).

## Table 4 Dietary fibre of Dough meal from blends of finger millet wild melon and eggplant flour

|  |  |  |  |
| --- | --- | --- | --- |
| Sample | Insoluble % | Soluble % | IDF:SDF |
| FM  100 | 45.03±0.05a | 12.27±0.12c | 3.1 |
| FWE3  **80:10:10** | 32.18±0.01c | 13.32±0.01b | 2:1 |
| FWE5  **10:10:80** | 25.35±0.03d | 10.65±0.02d | 2:1 |
| FWE7  **45:45:10** | 38.56±0.02b | 15.44±0.05a | 2:1 |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at (*P* < 0.05): Key: FM=Finger Millet 100% (CONTROL), FWE3= Finger millet 80%, Wild melon 10%, Eggplant 10%, FWE5= Finger millet 10%, Wild melon 80%, Eggplant 10%, FWE7= Finger millet 45%, Wild melon 45%, Eggplant 10%, IDF= insoluble dietary fiber, SDF= soluble dietary fiber.

3.7: The glycemic index and glycemic load of dough meals

The dietary glycemic index (GI) serves as a measure of carbohydrate quality, indicating its impact on blood glucose levels. Foods are often categorized into three classifications: high GI (>70%), medium GI (56-69%), and low GI (<55%). The glycemic index of dough meal varied from 38.00% in FWE7 to 49.25% in FWE5 (Table 5). The glycemic load of dough meal ranged from 21.24% in FWE7 to 31.53% in FWE3, in comparison to glucose (control) at 100%. This finding indicated that, the glycemic index (GI) and glycemic load (GL) of FWE7, composed of 45% finger millet, 45% wild melon, and 10% eggplant, were significantly lower compared to FM, FWE3, and FWE5 Despite all samples being classified as low glycemic index and moderate glycemic load foods, as they are below 56%, FWE7 exhibited a reduced GI and GL. This might be attributed to the variations in the quantity of finger millet (45%), wild melon (45%) and eggplant (10%) and the synergistic effect of phenolic compounds and dietary fiber, thereby, lowering blood glucose levels in diabetic individuals.  Foods with a low GI are digested more slowly, resulting in a smaller and slower increase in blood sugar compared to high GI foods (70 or more).  Numerous researches [52, 7] have indicated that the consumption of low glycemic index (GI) and glycemic load (GL) foods, typically diminishes the risk of diabetes, enhances insulin sensitivity, and may even lower serum cholesterol levels [3]. Consequently, the low glycemic index (GI) and glycemic load (GL) values seen in the FWE7 food samples may facilitate a rapid decrease in consumers' blood glucose levels.

## Table 5: Glycemic index and load (%) of dough meal

|  |  |  |
| --- | --- | --- |
| Sample | Glycemic index | Glycemic load |
| FM  100 | 41.41 | 29.61 |
| FWE3  **80:10:10** | 42.83 | 31.53 |
| FWE5  **10:10:80** | 49.25 | 31.15 |
| FWE7  **45:45:10** | 38.00 | 21.24 |
| GLUCOSE (CONTROL) | 100 | - |

Key Finger Millet 100% (CONTROL), FWE3= Finger millet 80%, Wild melon 10%, Eggplant 10%, FWE5= Finger millet 10%, Wild melon 80%, Eggplant 10%, FWE7= Finger millet 45%, Wild melon 45%, Eggplant 10%.

**4.0 CONCLUSION**

The study determined the proximate composition and antioxidant properties of various flours to evaluate their quality. The protein content ranged from 37% to 40%, and antioxidant properties exceeded 70 in the formulated blends. Among the four samples assessed, FWE7 (45% Finger millet: 45% Wild melon: 10% Eggplant) demonstrated significant levels of crude fiber, protein, and phytochemicals. Its high antioxidant content, dietary fiber, α-Amylase, and α-glucosidase indicate its potential to scavenge free radicals that can damage tissues. Additionally, the results suggest that, it may enhance insulin sensitivity and reduce glucose uptake in the body. Notably, the low glycemic index/load values indicate its suitability as a functional food for diabetes management when consumed appropriately*.* Further studies should be carried to validate these findings through in vivo trials (bioactive assay and biochemical analysis) and consumer acceptability test.

**AUTHOR´S CONTRIBUTION**- OSO: Conceptualization; supervision; writing – review and editing. AIO: supervision. LRI: Formal analysis; investigation; methodology; project administration

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3.

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