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ORGINAL RESEARCH ARTICLE

Influence of Aduwa (*Balanites aegyptiaca. del*) Meal Protein Enrichment on the Proximate, Phytochemical, Functional and Sensory Properties of Ogi

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ABSTRACT

Enrichment of Ogi using defatted Aduwa meal (DAM) and Aduwa concentrate (AC) at 16% protein inclusion by inclusion complexation approach was studied. Enrichment significantly improved the quality of the mix while a reverse trend was observed in sensory properties. The protein, fat, crude fiber, ash, functional properties, and total phenolic content of the enriched mix were high compared to Ogi- the control sample. The physiochemical and anti-nutrients analysis revealed that enriched DAM-ogi and AC-ogi are rich in functional nutrient and are safe for human consumption. The sensory parameters namely, color, texture, mouthful, aroma, appearance, and general acceptability of DAPM-ogi and APC-ogi were low when compared with control-Ogi. The DPM -Ogi and AC-Ogi enriched meals are brown in color as well as their flouring mix. The sensory appraisal revealed that the control -Ogi without enrichment received higher sensory scores when compared to the enriched mix samples.

Keywords: *Aduwa, defatted meal, concentrate, proximate, functional, anti-nutrient, sensory*

PRACTICAL APPLICATION

Bio functionality of plant-derived bioactive compounds is limited to application. pharmaceutic science has been interested in the bioavailability and biocompatibility of bioactive compounds. Bio-complexation method could make bioactive adhere to other food carries and therefore make them preserve and usable by home makers. The complexation encapsulating approach could play a fundamental role during transportation in the gastric system and may enhance other beneficial properties.

INTRODUCTION

Ogi is made from cereals such as maize or sorghum usually by the fermentation process. This gelatinized white pudding called pap is favourably used as a traditional weaning food and breakfast meal for many children and adults in Africa [1-2] During ogi making process, bio nutrients are lost from the grains during wet processing and drying thereby reducing the final product's nutritional profile. Most work on fortification with plant protein, such as okra, cowpea, and soybean [3-5] have been opined. However, these plant enrichers are limited by rheological and organoleptic acceptance [7]. This work aimed at enriching ogi with Aduwa proteins from defatted meals and Aduwa concentrate to improve ogi bio -nutrients and revealed their chemical behavior and sensory acceptance. *Balanites aegptiaca. del or Aduwa* in Hausa language is a popular traditional medicinal tree for a lot of ailments [8]. *B. aegyptiaca* seed flour has been reported with a good number of essential proteins, lipids, and minerals [9]. These proteins and peptides can afford to reduce malnutrition through functional supplementation and enrichment which could contribute to food security among dry land

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communities of Nigeria. ([10-11]. The use of defatted Aduwa meal and its protein concentrate to alleviate diabesity in Wister albino rats has been opined [11]. The study of the nutritional enrichment of *balanites aegyptiaca. del* seed defatted meal and concentrate with Ogi could expand the food candidacy for Sahel populated areas and other dry regions of the world. This study aims at understanding the physiochemical and functional properties of Ogi with non-cereal plant Aduwa seed protein meal for bio-nutrient density. Energy-protein crisis is a major health triggers experienced in developing societies [12]. The use of Ogi in African homes as a breakfast meal makes ogi a laudable medium for nutrient enrichment for hidden hunger reduction as well as malnutrition incidence. Aduwa meal proteins could be a good material to enrich Ogi which could play a significant role in improving cereal or ogi based diets for Nigerians. Ogi made from fermented maize are deficient in some nutrients [5]. It is limited in essential amino acids (lysine and tryptophan) with super essentiality [13] while oil seeds like Aduwa seed are rich in these essential proteins [14-15]. The general RDA guidelines and recent nutrition research recommend the consumption of 0.8 g of protein for every kilogram of body weight per day [16-17]. Therefore, 16 % target protein required for first 1000 days of a growing child was the basis for enriching Ogi by inclusion complexation method [18] using defatted Aduwa meal and Aduwa concentrate respectively. These could improve the nutritional value of the resulting flour blends against hidden hunger and malnutrition.

MATERIALS AND METHODS

Source of Raw Materials.

Twenty kilograms (20 kg) of B. *aegyptiaca* seed kernel*(Aduwa*) used for the study was bought from Gashua market, Nigeria. They were conveyed immediately to the biochemistry laboratory of the Federal University Gashua. Similarly, (20 kg) White Maize grains were bought from the North bank market in Makurdi for Ogi flour production.

Fifteen kilograms (15 kg) of seed kernels *of Balanites aegptiaca* del were weighted and moisture value ascertains using a moisture prop. The weighted samples were toast treated under dry heat at 70 ^{0} C for 30 minutes and then allowed to cool to room temperature before meal making.

Experimental Reagents

HCL, NaOH, H_2SO_4, Acetone, HCL, NaOH, H_2SO_4, iron 111 chloride, Diethyl ether, Ammonium thiocyanate sodium dodo sulphate (SDS) Were used and are of analytical grade, purchased from Sigma. Balanites seed and maize seeds were obtained from an accredited market in Nigeria. The meal and concentrate were packed in an airtight container stored in the freezer

Aduwa meal making

The seed kernels were subjected to toasting pre-treatment before milling, oil extracted, and the flour were molded into cakes. The cakes were milled into flour and oil from the flours was mechanically expelled using a centrifugal screw oil expelled from entrapped increased surface area at 60 revolutions per minute. The cake produced was dried using the solar cabinet dryer and well packaged and transported to the Federal University of Agriculture Makurdi, Food Chemistry and Cereal laboratories for analysis.

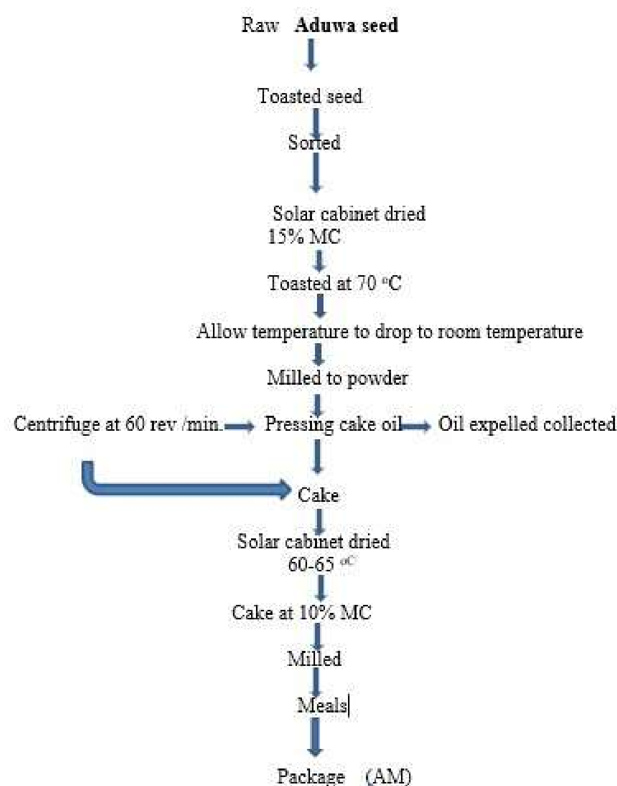

Fig 1 : Balanites aegptiaca .del Roasted Seed Meal Processing Source: [19]

Plate 1: Seed meals in Solar cabinet dryer

Defatted Aduwa seed meal (DAM) processing

The method by [20] was used to defat *Aduwa* meal. The flour sample was defatted with cold (4 ^{0}C) acetone using flour to solvent ratio of 1:5 w/v. The mixture was stirred over a magnetic stirred for 4 hr and was filtered through a Whatman No. 1 filter paper and residue was re-extracted twice in a similar fashion. The defatted flour was de-solvent zed by drying in a fume hood at room temperature and the dried flour was finally grounded using a blender to obtain a homogeneous mix of defatted *Aduwa* flour before being stored in an air-tight plastic bottle for use.

Preparation of Aduwa Concentrate (AC)

The method of [21] was adopted with some modifications. The defatted Aduwa meal was solvted using distilled water in a ratio of 1:5 (w/v), and the pH of the slurry adjusted to pH 10 with 1 M NaOH and then stirred for 2 hours at 30 °C. The extract was centrifugation at 2100 × g for 30 min at room temperature. The extracts were then precipitated by adjusting the pH to 4.0 with 1 M HCl before centrifugation at 3,000 × g for 30 min. The protein concentrate was washed with distilled water and then dissolved in distilled water and the pH was adjusted to 7.0 with 1 M NaOH prior to freeze-drying.

Ogi from maize grains production

The method of [22] for the traditional preparation of Ogi was adopted. The maize obtained was washed and steeped in clean water in a plastic container with cover. The water was decanted after three days (96 hrs) and the maize wet - milled into slurry. The slurry was sieved using a muslin cloth to separate the slurry white from the filtrate. The slurry was filtered, and oven dried at 50°C for 12 hrs and finally milled to flour.

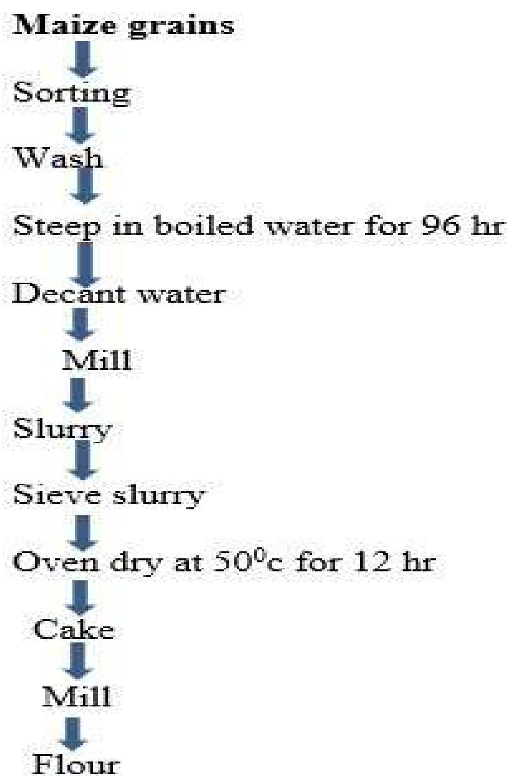

Fig :2 Making process of Ogi from maize cereal
Source: Oladeji *et al*.(2014)

Enrichment of Maize *Ogi* with Aduwa Seed Protein Products (by Material complexation method)

The dried ogi were milled to obtain the homogenous product. Defatted Aduwa meal and Aduwa concentrate were incorporated into dried maize ogi respectively following the formulation described by [18] on functional product making by material complexation approach to making functional Ogi -mix, (Table 1) to obtain a functional cereal flour; enriched with Aduwa proteins at 16% inclusion.

Preparation of Enriched Ogi by inclusion complexation method. [18,23] Modified.

Bottom –up approach of inclusion complexation was adopted [23]. Briefly, Aduwa protein samples and Ogi samples at an equivalent ratio of (16%) protein target inclusions (Table 1) were weighed accurately and transferred to a crucible. The mixture was then triturated with a small volume (1-2ml) of water to form a homogenous flow meal. The meal flour was mixed thoroughly using a kitchen blender, and the mixed meals were mildly dried. The final products were packaged.

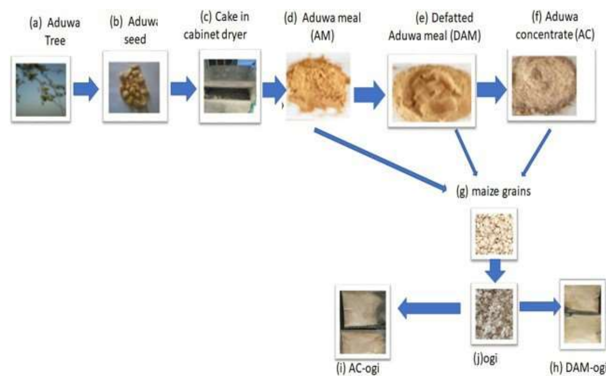

Plate 1. Summary on enriching process of defatted Aduwa meal Ogi and Aduwa concentrate Ogi

Table 1: Formulation of (16% protein target) Functional maize Ogi Based Cereal from defatted Aduwa meal, Aduwa meal isolate and hydrolysates

Enriched Ogi sample	sample A control(g)	sample B(g)	sample C(g)
Ogi flour (control)	100	68.57	55.95
DAM 16%+ ogi		31.43	
AC 16%+ ogi			44.05
Total (g)	100	100	100

Key:
Sample A =control
Sample B = Ogi and 16% Defatted Aduwa meal (DAM)
Sampl C =Ogi and 16% Aduwa concentrate (AC)

METHODS

Moisture content determination.

Five grams (5g) of Aduwa was weighed accurately into a pre-weighed clean dry dish. The uncovered dish was placed with its lid open in a well-ventilated oven maintained at 103°C for 3 hours. The dish was covered with a lid and transferred to a desiccator to cool for 30 minutes. It was re-weighed again immediately and the dish with the sample was placed in the oven for another 2 hours. The steps were repeated until decrease in mass were obtained.

$$\% \text{ Moisture content } = \frac{W1-W2}{W1-W0} \times 100 \quad \text{------------------------(1)}$$

Were

W_1 = Initial weight of crucible
W_2 = Weight of crucible + sample before drying
W_3 = Weight of crucible + sample after drying

Crude protein determination

Two grams of the sample were weighed into a digestion tube and 15ml of concentrated tetraoxosulphate (IV) acid (H_2SO_4) was added to dissolve the sample. The digestion process was initiated by Kjedhal tablet and then heating in a fume cupboard until it gave a clear solution. Distilled water (75ml) was added to prevent it from solidifying after digestion. The digest tube was placed in a distilling unit and 50ml of 40% NaOH solution was then used in the diluted solution, and the digested distillate into 25 ml of 40% boric acid for 5 minutes. The distillate was titrated against 0.47HCl until the first grey colour was seen. A blank was first titrated, and the titer value was recorded [24].

Ash content determination.

Ash determination was carried out using the method of [24]. Five (5) grams of dried sample was weighed and put in a crucible (W_2) and empty crucible weight as (W_1). The crucible was thereafter placed in the muffle furnace maintained at a temperature of 600°C for 6 hr. After the ash, it was then transferred directly to a desiccator and weighed immediately (AOAC, 2010).

$$\% \text{ Ash } = \frac{(\text{Weight of the crucible +Ash})-(\text{Weight of empty crucible})\times 100}{\text{Weight of sample}} \quad \text{---------------(2)}$$

Crude fat determination

Crude fat determination was carried out using the method of [24] . The thimble was cleaned, and the empty weight was recorded as W_1. Five (5) grams of oven- dried sample was added and re-weighed as (W_2). The bottom flask was filled up with petroleum up to three quarters of the flask. Soxhlet extractor was fixed with a reflux condenser to adjust the heat sources so that the solvent boils gently. The samples were then put inside the thimble and inserted into the Soxhlet apparatus and extraction under reflux was carried out with petroleum ether for 6 hours. After the barrel of the extractor became empty, the condenser and the thimble were removed. The thimble was taken to the oven at 100°C for 1 hour and later cooled in the desiccator. The sample was then weighed as (W_3).

$$\% \text{ Fat } = \frac{\textit{Weight loss of sample (extracted fat)}}{\textit{Original weight of sample}} \times 100 \quad \text{-----------------------(3)}$$

Crude fiber determination

Crude fiber content of the sample was determined using the method described in [24]. Two (2) grams

of sample were weighed and transferred into 250ml beaker. It was then boiled for 30 minutes with 100ml of 0.12M H_2SO_4 and filtered through a funnel. The filtrate was washed with boiling water until the washing is no longer acidic. The solution was boiled for another 30minutes with 100ml of 0.012MNaOH solution; filtered with hot water and methylated spirit three times. The residue was transferred into a crucible and dried in the oven at 103^0C for 1 hr. The crucible with its content was cooled in a desiccator and then weighed (W_1). The residue was then taken into a furnace to ash at 600°C for 1 hour. The ashes sample was removed from the furnace and put into the desiccator to cool and later weighed (W2). The percentage of crude fibre was calculated thus:

$$\% \, Crude \; fiber = \frac{W1 - W2}{Weight \; of \; sample} \times 100 \quad \text{----------------------------(4)}$$

Where:

W1 = Weight of crucible and residue in grams
W2 = Weight of final ashes sample in grams

Carbohydrate content determination

Carbohydrate determination was determined by difference

%Carbohydrate = 100%-%(Protein+Crude fat +Ash +Moisture +Crude fiber)

Determination of Phytochemical properties.

Determination of alkaloids

Alkaloid was quantitatively estimated using the method of [25]. Five (5) gram of sample was extracted in 200 ml of 10% acetic acid in ethanol in a 250 ml beaker. Samples were incubated for 4 H at room temperature, then filtered, and the filtrate was concentrated on a water bath to one-quarter of the original volume. The extracts were precipitated by the addition of drops of concentrated ammonium hydroxide and allowed to settle. The precipitates were washed with dilute ammonium hydroxide and then filtered. The residue comprised of the alkaloid was dried and weighed. The alkaloid content was determined using the formula:

$$\text{Alkaloid content} = \frac{weight \; of \; the \; dried \; residue}{weight \; of \; the \; origial \; sample} * 100 \quad \text{----(5)}$$

Total Phenolic Content (TPC)

The total phenolic content of the sample was determined according to the method described by [26]. Briefly, the sample was extracted by making a suspension of 50mg of the sample and garlic acid in 10 ml of distilled water. The sample was vortex every 10 minutes for an hour. The mixture was centrifuged to obtain the extract and 0.1 ml of the extract was diluted with 1.9 ml of distilled water and 1 ml of Folin-Ciocalteau's reagent (which has been previously diluted 10 folds). The mixture was incubated for 5 min and 1 ml of 7% sodium carbonate was added. The reaction mixture was incubated for two hours in the dark and the absorbance of the mixture was measured at 765 nm. The blank was also prepared in the following manner but without sample. The standard garlic extract was prepared at different concentrations of 100, 200, 400, 600, 800 and 1000 µg/ml to obtain calibration curve and the total phenolic content of the sample was extrapolated from the standard curve expressed as mg of garlic equivalents per gram of extract.

Determination of Saponin.

The saponin content is determined according to the method of [27]. One gram of the sample was mixed with 10 ml of 20 % ethanol. The sample was heated over hot water for one hour with continuous stirring at 55ºC. Mixture was filtered and the residue was reextracted with another 20mL of 20 % ethyl alcohol. The combined extracts were reduced to 10mL over a water bath at about 90ºC. The concentrate is then transferred into a 250mL separating funnel and 10 mL of diethyl ether is added to the extract and vigorously shaken. The aqueous layer was recovered while the diethyl ether layer is discarded. Twelve 12mL of *n*-butanol was added and the combined *n*-butanol extract was washed twice with 10mL of 5% sodium chloride. The left solutions were then heated in a water bath and after evaporation; the samples were dried in the oven to a constant weight and values were expressed in milligram per gram of extract.

Phytate Determination

About five 5 mL of the sample was mixed and allowed for five hours before filtration. An aliquot of 2500 mL of the filtrate in a conical flask was added to 5.00 mL of 0.30% ammonium thiocyanate and the mixture was titrated with standard iron (III) chloride solution to a persistent brownish- yellow coloration which persisted for 4 min. The amounts of phytates were calculated based on the formula by [28]

$$Phytic \; acid = Titre \; value \times 0.00195 \times 1.9 \times 100$$

Functional Properties of enriched Ogi with Aduwa defatted Aduwa meal and concentrates

Bulk density

About five (5) gram of flour sample was poured into a 100 mL measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density was calculated as weight of flour (g) divided by volume of flour (cm3). [29]

$$\text{Bulk density} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample(ml)}} \quad \text{--------------(6)}$$

Foam capacity (FC) and Foaming stability

FC was determined according to the method described by [30] using slurries that were prepared as 20, 40, or 60 mg/mL (protein weight basis) sample dispersions in 50 mL graduated centrifuge tubes containing 0.1 M phosphate buffer, pH 3.0, 5.0, 7.0, and 9.0. Sample slurry was homogenized at 20000 × *g* for 1 min using a blender. The capacity of the continuous phase to include air (FC) was determined as follows using the mean of 3 measurements.

$$\text{Foam Capacity(FC)} = \frac{\text{Vol.after homogenization} - \text{Vol.before homogenization}}{\text{Vol.before homogenization}} \quad \text{-----------(7)}$$

Foam Stability (FS). The ability to retain air for a certain period called foam stability was calculated by measuring the foam volume after storage at room temperature for 30 min and expressed as percentage of the original foam volume

$$\text{Foaming Stability (FS)} = \frac{\text{volume after standing} - \text{volume before whipping.ml}}{\text{Vol.before whipping.ml}} \quad \text{-----(8)}$$

Water Absorption capacity (WAC)

The WAC was evaluated using the method of [30] with slight modifications. A Protein sample of one gram was dispersed in 10 mL distilled water in a 15 mL of pre-weighed centrifuge tube. The dispersions are vortexed for 1 min, were allowed to stand for 30 min and then centrifuged at 7000 × *g* for 25 min at room temperature. The supernatant was decanted, excess water in the upper phase was drained for 15 min and the tube containing the protein residue was re-weighed to determine amount of water retained per gram of sample.

The Oil Absorption capacity (OAC)

The OAC was determined using the method of [30] with slight modifications. A Protein sample of one gram was dissolved in 10 mL pure canola oil in a 15 mL pre-weighed centrifuge tube. The dispersions were vortexed for 1 min, allowed to stand for 30 min, and then centrifuged at 7000 × *g* for 25 min at room temperature. The supernatant was decanted, excess oil in the upper phase was drained for 15 min and the tube containing the protein residue was weighed again to determine the amount of oil retained per gram of sample.

Swelling index

The swelling index was determined according to the method by [31].Two (2) grams of the flour sample were poured into a 50ml measuring cylinder and the volume it occupied was recorded. Already boiled water was added up to 50ml mark and the measuring cylinder was allowed to stand for 45mins after which the new volume of flour was recorded. The ratio of the initial volume to the final volume was taken as the swelling index.

$$\text{Swelling index} = \frac{\text{change in volume of sample (ml)}}{\text{Original volume of sample(ml)}} \cdot \text{-----(9)}$$

Emulsifying index

Emulsifying activity index (EAI) and emulsion stability index (ESI) were determined using the method modified by [30]. Protein slurry of. 10, 25, or 50 mg/ml each were mixed with 30 ml of deionized water. This protein solution was mixed with 10 ml of sunflower vegetable oil, and the pH was adjusted to 3, 5, 7, and 9. Mixture was homogenised at a speed of 20,000 rpm for 1 min. Fifty microlitres (50 mL) of the aliquot of the emulsion were transferred (using pipette) from the bottom of the container at 0 and 10 min after homogenization and mixed with 5 ml of 0.1% sodium dodecyl sulphate (SDS) solution. The absorbance of the diluted solution was measured at 500 nm using a spectrophotometer (BIO-TEK Kontron, Germany). Th EAI and ESI were calculated thus.

Emulsifying activity index (EAI) m2/g

$$\text{EAI} = \frac{2\text{x}2.303\text{x Ao}}{0.23\text{xprotein weight g}} \quad \text{----------(10)}$$

Emulsion stability index (ESI) min

$$\text{ESI} = \frac{\text{A10 x Dt}}{\text{DA}} \quad \text{--------------------------------(11)}$$

where A_0 is the absorbance at 0 min after homogenisation; A10 is the absorbance at 10 min after homogenisation; Dt = 10 min; and

DA = (A0 - A10)------------------------------------(12)

Least gelation concentration (LGC)

Least gelation capacity (LGC) was determined according to the method described by [30] with slight modification. One gram sample were suspended in water at different concentrations (2% to 20%, w/v, protein weight basis). The mixture was vortexed, placed in a water bath at 95 °C for 1 h, cooled rapidly under tap water and left in the refrigerator (4 °C) for 2-14 h. The sample concentration at which the gel did not slip when the tube was inverted was taken as the LGC.

Percentage Protein Dispersibility

Dispersibility was determined by using the method described by [32]. About 10g of the samples were weighted into a 100ml measuring cylinders and water added to make up to 100ml. The stubes were stirred vigorously and allowed to stand for three hours. The volumes of settled particles were taken and subtracted from 100.

% Dispersibility = (100 -Volume of settled particle) ---(13)

DISCUSSION

Proximate Composition of starting Aduwa protein Meals and Concentrate

The moisture content of the desert date *Aduwa* meal sample DAM (4.96%) and AC (5.31% were significantly different at (p>0.05) from the control-Ogi. Defatted *Aduwa* protein meal (4.86%) has significantly high fat content (p>005) than APC (0.46%) as well as the control-Ogi sample (4.83%). According to [14] ,39.63% fat content has been reported on raw desert date kernel extracted using an organic solvent. This result is supported by similar results by [33-35].The defatted *Aduwa* meal seed protein in this study was found to contain an appreciable amount of crude fiber (4.01%) that was significantly higher than Aduwa- concentrate AC (1.84%) and control-ogi (0.70%) .This study revealed that the percentage protein content of the *Aduwa* meal samples was significantly different as sample meals were resolved to defatted meal and concentrate. The Crude protein content of Aduwa meals were DAM (35.67%), AC (62.23%) and control (6.36 %) respectively. The crude protein value observed in AC was significant and higher than DAM and the control samples. The ash content of the meal sample was found to be significantly different at (p>0.05) as sample meals were resolved. Defatted *Aduwa* meal DAM (15.38%) is higher than control (1.29%) and AC (1.23%) respectively. This result agreed with the report values published by [34-35]. The carbohydrate content of the Aduwa meal sample was significantly different. Aduwa protein concentrate AC (29.9%) has higher energy value differently at (p>0.05) than DAM (27.11%) and AC (27.88%). These values are higher than 7.48% values reported by [14,34-35]

Proximate properties of Ogi enriched with *Aduwa* protein meal and concentrate

Proximate composition of enriched Ogi is shown in Table **3.** Proximate value of the enriched based ogi increased with material enrichment. The percentage of protein, moisture content, fat, ash, and crude fiber significantly increased when compared to the control -ogi sample. There exist significant differences in protein content between the control with 100% maize ogi and the defatted *Aduwa* protein DAM and protein content in AC –ogi sample. The Aduwa enriched ogi was found to have high crude protein content similar to that reported in Aduwa seed cake [37], soybean meal [38],Aduwa leaves [38], Aduwa flower and fruit pulp [8]. The enriched samples also had higher protein content than the pulp [36]. The protein value in this study agreed with the value obtained from the Much room -ogi made sample by [40]. About 50% ground nut meal inclusion with 50% ogi made product reported by [6] when groundnut seed were fortified with ogi at 8.63% and 100% blend rations respectively. The 100% showed 14.23% protein value, however lower than the present study result. Similarly, [41] revelated a high 6.9% protein value when cray fish was fortified with ogi. The high protein content in the enriched samples which is however lower than the referral values obtained in Table 2 above could be due to the starch molecules from the Ogi sample were able to occlude the conformation of protein meal and the protein concentrate moieties. This occlusion may have resulted in the observed increase in protein content of the *Aduwa* -enriched maize ogi, which could be argued due to nutrient contribution from the *Aduwa* proteins samples.

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Table 2: Proximate Composition of Aduwa Meals, and Concentrate,

Sample	Moisture Content (%)	Fat (%)	Crude Fibre (%)	Protein (%)	Ash content (%)	Carbohydrate (%)
Control (Ogi)	$2.53^{c}\pm0.09$	$4.83^{b}\pm0.01$	$0.70^{c}\pm0.01$	$6.36^{c}\pm0.01$	$1.29^{c}\pm0.14$	$84.29^{a}\pm0.36$
DAM	$7.49^{a}\pm0.040$	$4.86^{a}\pm0.007$	$4.01^{a}\pm0.726$	$35.67^{b}\pm22.51$	$15.38^{a}\pm23.8$	$32.59^{c}\pm22.1$
APC	$6.30^{b}\pm0.117$	$0.46^{c}\pm0.026$	$1.84^{b}\pm0.010$	$62.23^{a}\pm0.05$	$1.23^{b}\pm00.02$	$27.94^{b}\pm0.1$

Mean value is from three determinations. Means followed by the same alphabetic on the column are not significantly different at $p>0.05$

Key: DAM =defatted Aduwa meal, AC= Aduwa concentrate.

The moisture content is significantly different having the enriched sample with higher moisture content above the control at ($p<0.05$). The observed moisture value was lower than the moisture value reported by [40] when crayfish flour was used to enrich Ogi. This observation was also noticed in fat content of the samples. The fat content of AC-ogi and control-ogi were significantly high than the defatted sample (DAM-ogi). There exist significant differences among the samples at ($p<0.05$). However, the crude fat content in the sample is quite comparable with Aduwa fruit pulp crude fat value reported by[33,6] . There exists a significance difference between AC -ogi and DAM-Ogi ($p>0.05$) on ash content, but DAM-ogi is higher than the control-ogi. Enrichment significantly increased ash content of Ogi functional mix. The ash content was lower than that found in *Aduwa* pulp as described by [36]. Since ash is the index of mineral content, the enriched Ogi samples with Aduwa proteins have high mineral contents compared to the pulp of the fruit [33] .

The crude fiber content of the control and Aduwa protein concentrate were not significantly different at ($p<0.05$), but lower than DAM-Ogi .Crude fiber in *Balanites aegyptiaca or Aduwa* enriched Ogi is quite significantly high , however higher in defatted *Aduwa* resolved samples than the AC-Ogi and control-ogi sample respectively .Low crude fibre content in nuts could lead to constipation if excess of it are been consumed because crude fibre enhances bowel movements. The energy content through the carbohydrate values shows that the control ogi sample significantly has (p<005) high carbohydrate value than the enriched Ogi sample. The dietary requirement for high protein and low carbohydrate diets (ketogenic diets) by consumers for obvious reasons, particularly for nutritional and health benefits is necessitating the need for protein-enrichment of food products. Ogi is a local but popular meal among adults and is commonly used as a weaning food and for convalescence. It is however low in nutritional quality due to a lack of essential amino acids. Therefore, enrichment of ogi with *Aduwa* protein meal will improve ogi protein quality and invariably enhance nutritional quality of these breakfast staple meal among Nigerian .

Functional Properties of Enriched Ogi with *Aduwa* meal and protein concentrate

Bulk density, swelling index, Water absorption capacity, Oil absorption capacity, foaming capacity least gelation capacity reconstitution index and Dispersibility of enriched Ogi are shown in Table 4. Bulk density applied to packaging sense and technology as well as application processing in the food industry. The lower the bulk density, the higher the number of particles that could bind together which may lead to high energy values. In addition, higher bulk density is desired since it helps to lower past thickness which is an important factor for sick child feeding. The DAM-ogi had a high bulk density significantly compared to AC-ogi and the control-ogi respectively. The 0.4g/g bulkiness from the control-ogi sample are significantly different with better good packaging properties however lower than AC-ogi and DAM-ogi with excellent weight and space relationship. This observation could be due to the much air spaces in the control sample.

The Swelling index (SI) of AC-ogi and DAM-ogi samples were observed to be significant ($p<0.05$) but differ from the control-Ogi sample. The Aduwa concentrate AC-ogi and DAM-ogi had less leachable biomaterials when compared to control- ogi sample. These changes could be attributed to biomaterial stepwise leaching during heating, this critical

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Table 3: Proximate Composition of Ogi enriched with defatted *Aduwa* meal and Protein Concentrates

sample	Protein (%)	Moisture (%)	Fat (%)	Ash (%)	Crude fibre (%)	CHO
Control-ogi	6.36c±0.01	2.53c±0.09	4.83b±0.01	1.29c±0.14	0.70c±0.01	84.29a±0.36
DAM-Ogi	14.75b±0.36	2.75b±0.09	4.03c±0.00	3.95a±0.08	0.91b±0.01	73.61c±0.01
AC-ogi	23.55a±0.63	6.58a+0.028	5.55a+0.01	2.58b+0.03	0.50c+0.01	61.24e+1.24

Mean is from triplicate determinations; Means followed by the same alphabetic on the column are not significantly different at p>0.05
Key: control, DAM-ogi =defatted *Aduwa* meal and Ogi, AC-ogi= *Aduwa* concentrate and ogi,

observation could be attributed to the simi-folded or unfolded nature of protein in AC-ogi and DAM-ogi, binding tight to ogi-free biomaterials. The Swelling index of the sample is an indicator of the water absorption capacity of the mix granules during heating. The swelling capacity of food material confers the ability to form bulkiness when incorporated into the food system. The AC-ogi and DAM-ogi samples when hydrated under certain thermal condition could release most bonded biomaterial with high swelling capacity, indicating that they could be better preferred in food systems, hence better samples for an organoleptic mouthful.

The water absorption capacity (WAC) of the sample increased with an increase as Aduwa materials are being resolved into defatted and concentrated samples. Sample AC +ogi had the higher WAC (1.44 g/ml), followed by sample DAM +ogi C (1.35g/ml) and the control recorded the least value of WAC (1.03 g/ml). The water absorption capacity (WAC) is desirable for the improvement of organoleptic in food products. An increase in water absorption capacity in the functional mix might be due to thickness of the interfacial bi-layer model of protein-to-protein interaction and this was observed to increase with the increase in the *Aduwa* proteins. This advantage could be attributed to its protein- folded nature when enriched with ogi. The ability of food material micelles to hold water molecules depends on the conformational position of the starch or protein material, size, and charge present Chavan et al. (2001). According to [42] this behaviour is attributed to the hydrophilic or hydrophobic balance of the residual amino acid in the material, polar amino acid, ionic strength, and lipids which are observed in AC-ogi sample. The WAC in AC-ogi sample was higher than DAM-ogi while the control had the least WAC values. The values obtained on WAC for DAM-Ogi, and APC-ogi (1.35-1.44) g/m were low compared to the value reported by (Ajanaku et al.,2017) on crayfish ogi attributed to lipid interaction.

The Oil absorption capacity (OAC) of both the control and enriched samples varied in a similar fashion to the WAC. Palatability and chewability are enhanced by OAC, this trend in water and oil absorption was observed by [19] in enriched ogi with soy peptides. The OAC increased with the enrichment of Aduwa protein in ogi samples between the range of 0.61 to 1.58% which were significantly (p>0.05) higher than that of the control sample (0.39%). The least gelation concentration of AC -ogi is significantly higher than DAM-ogi. Table 4. Indicated that the control -ogi sample had low LGC of (17 %). Similarly, samples DAM-ogi and AC-ogi had the high but similar LGC of (12% and 13 %) respectively. High level value in least gelation capacity according to Osemwota et al. (2021) could means less thickening capacity of enriched product which is the reason why the control sample was associated with the low LGC (17.0%) and low moisture content compared to the enriched samples (13-12%) LGC. The high GC in DAM-ogi and AC-ogi could be due to protein folded conformation and hydrophobicity, resulting from precipitation and heat annealing processes during production

Foaming capacity FC

Foams are formed when protein materials are dispersed and then held at air water interphase thereby decreasing surface tension when the proteins are partially or fully unfolded. This implies that high foam capacity connotes high protein content in the given sample. Hence, air incorporation resulting in an increased volume defines foam capacity. The high significant value (p>0.05) observed was in AC-ogi (15.15%) followed by DAM -ogi (1.0%) and the control with the least value (0.30%). The AC-ogi showed greater foaming properties which could translate to high solubility observed in WAC and dispersibility index results. The high foaming index observed in AC-ogi could be due to folded/unfolded occluded ogi starch protein hydration mechanism, while the DAM-ogi may still be folded during step wise hydration process, limiting the protein -protein

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Table 4: Functional Properties of enriched ogi with Aduwa defatted Aduwa meal and concentrates

Sample	Bulk Density	Swelling Index	WAC	OAC	Foaming capacity	LGC	Percentage Dispersibility%
Control-Ogi	0.40^{c}±0.00	0.16^{a}±0.00	1.03^{b}±0.01	0.39^{c}±0.01	0.30^{c}±0.00	17.0^{a}±0.00	76.00^{c}±0.00
DAPM+Ogi	0.85^{a}±0.07	0.08^{b}±0.00	1.35^{b}±0.00	0.61^{b}±0.00	1.00^{b}±0.00	13.0^{b}±0.00	76.50^{b}±0.71
APC+Ogi	0.53^{b}±0.04	0.08^{b}±0.00	1.44^{a}±0.20	1.58^{a}±0.20	15.15^{a}±21.0	12.0^{c}±0.01	78.00^{a}±0.00

Mean are readings from triplicate determinations; Means followed by the same alphabetic on the column are not significantly different at p<0.05
Key: Control, DAM-ogi =deffated *Aduwa* protein meal and Ogi, AC-ogi= *Aduwa* concentrate.

interaction needed to form an interfacial membrane for foam promotion.[44] .

Percentage Dispersibility

The ability of the material samples to disperse easily in solution decreased (p>0.05) significantly but went up with AC-ogi sample. AC-ogi (78%) had the highest value followed by control and DAM-ogi (75.5%) with the least dispersibility index. The constitution and reconstitution ability of APC-Ogi an in aqueous medium was high compared to DAM, however, DAM was not resolved via acid or base solubilization.

Phytochemical Properties of enriched ogi with Aduwa defatted Aduwa meal and concentrates

Phytochemical screening of enriched *Aduwa* ogi reveal the presence of alkaloids, total Phenol, tannins, Saponins and phytate. Alkaloid content observed in this study was higher than that reported for the seeds of *Daniella Oliveri* and *Olax subscorpoidea* [46] and *Balanites aegyptiaca or* Aduwa flower [45]. The Low dose of alkaloids mediates important pharmacological activities, reduces blood pressure, kills tumor cells, and stimulates circulation and respiration [47]. About (0.89) % was found in the control –ogi and AC-ogi (0.99) %, however lower than in DAM-ogi (1.01) %

Phenolic is a conjugate bioactive but varies in the present samples, DAM-ogi (10.26) % and APC-ogi (10.05) % having high phenolic material lower than the control sample (9.74) %. This reveals that *Aduwa* proteins enrichments affected phenolic content. Hence the functional ogi mix could reduce antimicrobial agents and inhibit growth of pathogens. Report by [48] revealed that in human nutrition, phenolic compounds have been reported to release anti-microbial, anti-inflammatory and antioxidant properties. The phenolic content in this study increased significantly as protein meal materials were used to enrich ogi. The obtained result in this study were lower compared to values reported by [19] for soaked *Balanites aegyptiaca* meal flour (2.8 mg/g) and roasted meal (4 mg/ g) samples. Phenolic content has been attributed to antioxidant potentials, α-amylase and α–glycosidase enzymes inhibitory and binding abilities [48]. A lot of secondary plant metabolites known as phytochemicals are known to be important but could also be harmful especially when consumed in large quantities, hence called anti-nutrients [11].

Tannins are a Phyto anti -nutrient substance. The tannin content in the control-ogi and APC-ogi were lower than DAM-ogi. This variation could be attributed to processing method before inclusion enrichment. Tannin has been reported to be able to bind certain proteins by combining with digestive enzymes thereby making the protein unavailable for digestion [49]. Saponins are glycosides occurring in wide variety of plants and associated with bitter taste, foams in aqueous solutions, and could haemolyse red blood cells due to their stereo affinity [15]. However, they are non-poisonous to warm blooded animals. Aduwa therapeutic ability [50] but at high dose saponin could cause gastroenteritis or leaking guts which could manifest by diarrhoea and dysentery [15,53]. The saponin content in control (0.08mg/g) and enriched sample DAM-ogi (0.18mg/g) and APC –ogi (0.12mg/g) has a very low level of saponin. According to Muhammed et al. (2002) saponin lethal dose of 1-600mg/kg has been proposed, however, the control-ogi and AC-ogi have low saponin below the threshold of lethality. This reduction could be due to protein extraction method used. Various studies have revealed saponins pharmacotherapeutic abilities (Egbuna and Ifemeje, 2015). Which agreed with this study values.

Phytate chelates cations like calcium ion, magnesium, and zinc ions as well as certain enzyme activity[51] The phytate in enriched ogi with Aduwa protein samples reduced significantly (*P* >0.05). Phytate

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Table 5: Phytochemical Properties of enriched ogi with Aduwa defatted Aduwa meal and concentrates

Treatment/sample	Control	DAPM -ogi	APC- ogi
Alkaloids (%)	0.89c±0.00	1.01a±0.00	0.99^{b}±0.01
TPC (mg GAE/g)	9.74b±0.02	10.26^{a}±0.03	10.05^{a}±0.02
Tannin (mg CAT/g)	0.26^{c}±0.03	0.34a±0.02	0.29b±0.01
Saponin (mg/g)	0.08^{c}±0.02	0.18^{a}±0.01	0.12^{b}±0.01
Phytate (mg/g)	0.09^{a}±0.02	0.14^{b}±0.02	0.09^{a}±0.01
LSD	0.00	0.00	0.00

Mean are readings from duplicate determinations; Means followed by the same alphabetic on the column are not significantly different at p>0.05
Key: Key: control, DAM-ogi =defatted *Aduwa* meal and Ogi, AC-ogi= *Aduwa* concentrate and ogi.

Table 7: Sensory evaluation of enriched Ogi with Aduwa defatted Aduwa meal and concentrates

Sample	Colour	Texture	Taste	Mouthful	Aroma	Appearance	General acceptability
Control	8.18a± 0.02	7.62a±0.01	7.26a±0.00	6.50a±0.00	6.57a±0.03	8.40a±0.01	7.98a±0.02
DAPM-Ogi	5.76b±0.04	5.50b±0.07	5.46b±0.00	6.11b±0.07	4.33c±0.07	5.80b±0.00	5.27b±0.36
APC-Ogi	4.95c±0.07	5.29b±0.01	3.38c±0.02	4.21c±0.07	5.06b±0.07	4.28c±0.02	4.95c±0.07

Mean are readings from duplicate determinations; Means followed by the same alphabetic on the column are not significantly different at (p>0.05)
Key: control, DAM-ogi =defatted *Aduwa* p meal and Ogi, AC-ogi= *Aduwa* concentrate and ogi ,

content of control-ogi (0.1mg/g) and AC –ogi (0.09 mg/g) are the same but significantly differ in DAM-ogi (0.14 mg/g). These values are lower than the values reported for peas (601.80 to709.74 mg/g). Moisture content reduction in sample matrix has been attributed to reduction effect in phytate content [51]. It has been reported that phytic acid ingestion between (4-9 mg/ g) could reduce iron absorption by 4 to 5 folds in human [52]. Coincidentally, enriched ogi sample has less level of phytate hence safe for consumption.

Sensorial Evaluation

The taste panel assessment of the enriched blends is shown in Table 7, the sensorial quality attribute of all the samples. The results analysed for colour, texture, mouthful, aroma, appearance, and general acceptability indicated that the Control-ogi is significantly different from DAM-ogi and APC-ogi at p>0.05%. Similarly, DAM-ogi is significantly difference from AC-ogi samples for taste, mouthful, aroma, and appearance. This point out that DAM-ogi is mostly preferred after the control sample. Furthermore, AC -ogi is preferred for colour, texture, and mouthful and not significantly different (p>0.05) from the DAM-ogi apart from the control-ogi blend. For overall acceptability, the control -ogi has value above 70% while DAPM-ogi and APC-ogi are less, indicating the acceptance of the control – ogi sample

Conclusion

This study concluded that enriched ogi with defatted *Aduwa* meal and Aduwa concentrate proteins exhibited a good range of proximate, functional, and phytochemical profile with enriched samples having high protein, ash, foaming capacity, water, and oil absorption capacities values higher than control -ogi sample. Samples has promising low anti - nutrients especially in AC-ogi. Thus, enriched ogi protein products from *Aduwa* proteins could find useful application in protein fortification and enrichment of ogi and other foods.

Authors contribution

Ogori Akama Friday performed the experiments and analysed the results. Girgih Abraham. Designed the experiment and analysed the data, supervised, and wrote the third draft, Eke Ojotu Mike wrote the first and Abu Oneh.Joseph wrote the second draft of the manuscript and read and edited the manuscript

Declaration of Competing Interest

The authors declared no conflict-of-interest

Availability of data and material

Not applicable.

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Consent for publication

All the authors agreed to publish this article in this journal

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