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

By

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Abstract

The study aims to enriched ogi using *Aduwa* defatted protein meal and protein concentrate at 16% protein target inclusion (ogi control only, ogi + 16% protein inclusion with defatted *Aduwa* protein meal and 16% inclusion with *Aduwa* protein concentrate. Enrichment of ogi with *aduwa* proteins significantly ($p<0.05$) improved the proximate phytochemical and functional properties of the mix while a reverse trend was found for sensory properties.. The protein, fat, crude fibre, ash, bulk density, water absorption capacity, oil absorption capacity foam capacity, percentage dispersibility and total phenolic content of the enriched mix were significantly ($p<0.05$) higher as compared to control-ogi. The sensory parameters namely colour, texture, mouthful, aroma, appearance, and general acceptability of DAPM-ogi and APC-ogi were significantly ($p<0.05$) lower than the control-ogi (100% maize ogi). Further, DAPM -ogi and APC-ogi enriched meals were brown in colour and a flouring mix, the sensory appraisal revealed that the control - ogi without enrichment received high sensory scores comparable to the enriched mix samples. The physiochemical and anti-nutrients analysis revealed that enriched DAPM-ogi and APC-ogi are rich in nutrients and are safe.

Keywords: *Aduwa* ,defatted meal, concentrate, physiochemical, phytochemical, enrichment

Introduction

Fermented cereal pudding prepared from maize or sorghum called ogi are in many parts of Nigeria and Africa; a gelatinized white pudding called pap favourably used as a traditional weaning food and breakfast meal for many adults in Africa (**Ogodo *et al*., 2015**). In Nigeria, it is called akamu amongst the Igbo, Ogi or Akamu in Yorubas and Koko in the Hausas with a consistency like American pudding (Ogori et al., 2020). Most nutrients are lost from the grains during wet processing and drying thereby reducing the nutritional load adversely. To improve the nutritional value of Ogi, researchers have fortified it with plant protein, such as, okro, cowpea, and soybean (Nnamezie, **et al 2021**; Aminigo and Akingbala, 2004; Ajanaku et al., 2012).However these plant enrichers are limited by rheological and organoleptic acceptance (Osungbaro, 2009). For this study,Ogi will be enriched with *Aduwa* protein defatted meal or protein concentrate to improve ogi bio nutrients and revealed their pasting and sensory acceptance. *Balanites aegptiaca or Aduwa* in Hausa language is a popular traditional medicinal tree for a lot of ailments (**Okai *et al*., 2013**). *B. aegyptiaca* seed powder contains a relatively high amount of protein and lipid, sugar, carbohydrate, and minerals such as potassium, calcium in significant amount (**Mustapha *et al*., 2003**). *Balanites aegyptiaca* seed meal protein products can afford to reduce malnutrition through functional supplementation, enrichment and thereby contributing to food security and reduce poverty among dry land communities of Nigeria. (Ogori et al., 2020; NRC**, 2008**). The use of defatted Aduwa meal and its protein concentrate to alleviate diabesity in Wister albino rats has been opined by (Ogori et al., 2022). The study of the nutritional enrichment of *B. aegyptiaca* seed protein meal and protein concentrate with Ogi could expand the food candidates for populations of Sahel and other dry regions of the world. Hence, 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 mal-nutrition has been one of the major health triggers experienced in developing societies including Nigeria (Ubesie *et al.,* 2012). Ogi is consumed in African homes as breakfast meal and children's substituted meal for breast milk and will be a laudable medium for nutrient enrichment for the reduction of malnutrition incidence. Aduwa meals proteins could be good ogi -enricher alternative and could play a significant role in improving cereal or ogi based diets of Nigerians. Ogi made from fermented maize, is known from research to be deficient in some nutrients such as certain protein, vitamins, and mineral (Ajanaku et al., 2012). but Ogi is limited in essential amino acids (lysine and tryptophan (Omole et al., 2017) while oil seeds like Aduwa seed is rich in these essential amino acids (Datti et al.,2020; Mohammed et al., 2000). The general RDA guidelines and recent nutrition research recommends the consumption of 0.8 g of protein for every kilogram of body weight per day (0.9 g/kg/day) (Carol *et al.,* 2019: WHO, 1989), Therefore 16 % target protein required for first 1000 days of a growing child was the basis for enriching Ogi by inclusion complexation method (Vikram et al.,2008) using defatted Aduwa protein meal and Aduwa protein concentrate respectively. Thus, combining Ogi flours with addition of Aduwa derived meal proteins; concentrate will improve the nutritional value of the resulting flour blends against hidden hunger and malnutrition.

MATERIALS AND METGHODS

Source of Raw Materials.

Twenty kilograms (2 kg) of mature *B. aegyptiaca fruits (Aduwa*) used for this study were bought from Gashua market in Yobe State of Nigeria. They were transported immediately to the biochemistry laboratory of the Federal university Gashua. Similarly, about 2 kg White Maize grains were bought from north bank market in Makurdi for Ogi flour production.

Fifteen kilogrammes (1 kg) of cracked seed kernels *of Balanites aegptiaaca* were weighted using a weigh balance and moisture value ascertain at 15% using moisture prop (E20 USA

Model 121). The weighted samples were apportioned to toasting treatments under dry heat at 70 ^{0} C for 30 minutes and allowed to cool.

Aduwa Seed processing and meal making

The seed kernels were subjected to toasting pre-treatment before milling, oil extraction and meal caking. The cakes from the seed milled flours were mechanically expelled using centrifugal screw which is semi-automated for meal making and oil expelled from entrapped increase surface area at 60 revolutions per minutes Ogori *et al*. (2019) .The flow chart of the treatments processes is shown in Figure 1.

The cake produced were dried to 10% MC using the solar cabinet dryer and well packaged and transported to the Federal University of Agriculture Makurdi, Food Chemistry and Cereal laboratories for analysis.

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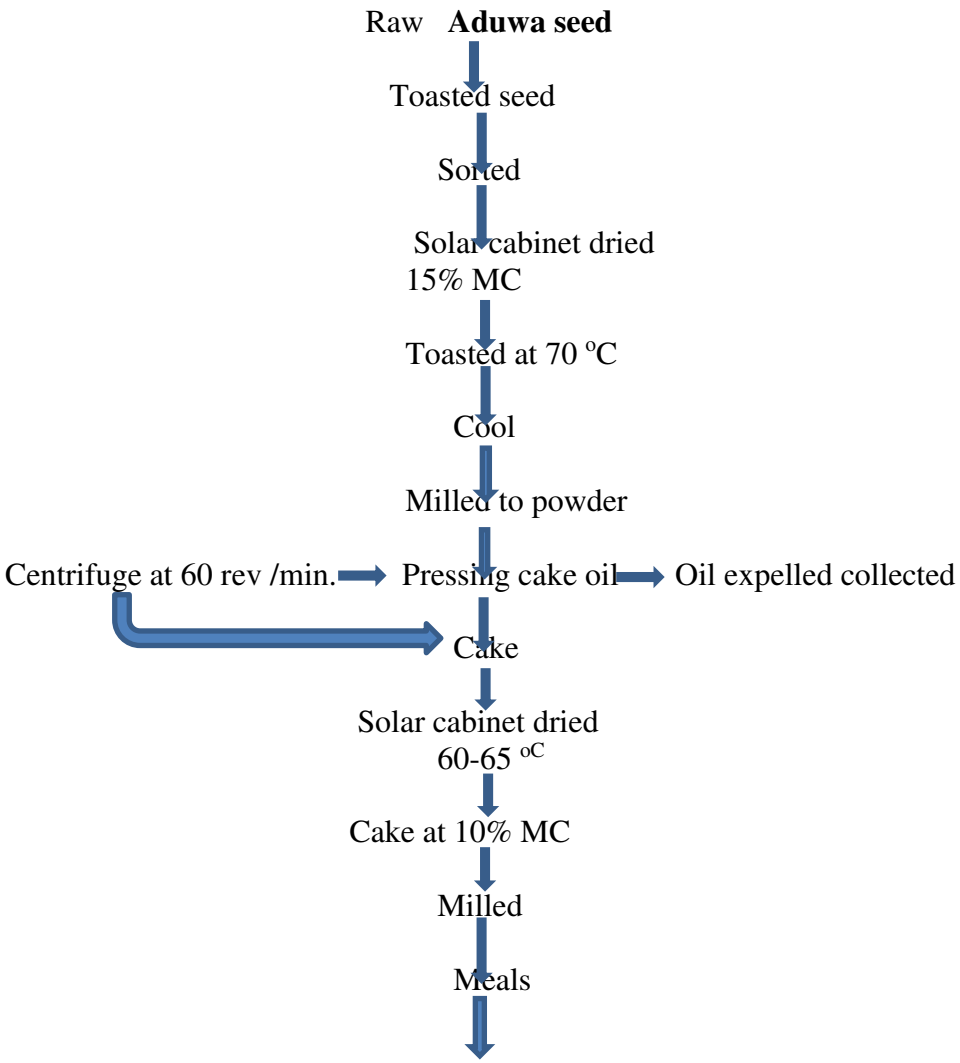

Package (APM)

Fig 1 : Flow chart for Balanites Aegytypiaca Roasted Seed Meal Flour Processing Source: (Ogori *et al.,* 2019)

Plate 1 : **Seed meals in Solar cabinet dryer**

Preparation of defatted Aduwa seed meal (DAPM)

Preparation of Defatted *Aduwa* seed meal flours were prepared from toasted seed made into flour sample (fig 2). The method of Sathe, (1994) as modified by Gbadamosi *et al*. (2011) was used to defat *Aduwa* meal. The flour sample was defatted with cold (4 ^{0}C) acetone using a flour to solvent ratio of 1:5 w/v. The mixture was stirred over a magnetic stirred for 4 hrs. The slurry was then filtered through a Whatman No. 1 filter paper. The residue was re-extracted twice in a similar fashion. The defatted flour was de-solventized by drying in a fume hood at room temperature and the dried flour was finally ground in a blender to obtain homogeneous defatted *Aduwa* flour and stored in an air-tight plastic bottle for use.

Preparation of aduwa Protein Concentrate (APC)

Protein concentrate was prepared according to the procedure described by Olayide .(2013), with some modifications. The defatted aduwa meal was dispersed in distilled water at meal to water ratio of 1:5 (w/v); the pH was adjusted to pH 10 with 1 M NaOH and stirred for 2 hours

at 30 °C. The extract was separated by 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 (pH 4.2) 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. The dry protein concentrates were stored in airtight glass containers for subsequent analyses.

Preparation of Ogi from maize grains

The maize samples were sorted to ensure wholesomeness. Fermentation of whole grain followed the method of Oladeji et al. (2014) for traditional preparation of ogi. The maize obtained was washed and steeped in clean boiled 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 muslin cloth, which separated the pomace from the filtrate. The slurry was filtered, and oven dried at 50^{o}C for 12 hrs. The dried ogi cake was fine milled to flour.

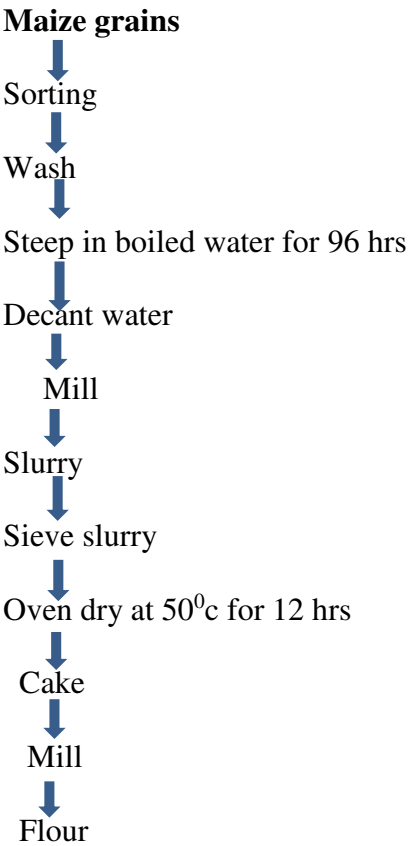

Fig :2 Production of Ogi from maize cereal
Source :Oladeji *et al*.(2014)

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

The dried ogi were milled to obtain homogenous product. Deffated Aduwa meal and aduwa protein concentrate, were incorporated in dried maize ogi respectively following the formulation described by **Vikram et al .(2008)**) on functional product making by material complexation for making functional ogi mix, (Table 1) to obtain functional maize *ogi* flour; enriched with Aduwa seed meal proteins with protein target of 16% .

Preparation of Enriched Ogi by inclusion complexation method. (Vikram et al .,2008; Ezhilarrasi et al (2013) **Modified .**

Bottom –up approach of inclusion complexation was adopted Ezhilarrasi et al (2013) Briefly, Aduwa protein samples and Ogi sample at equivalent ratio of (16%) protein target inclusions (Table 1) were weighed accurately and transferred to a crucible. The mixture was then triturated with small volume (1-2ml) of water to form homogenous flow meal. The meal flour was mixed thoroughly using kitchen blender, and the mixed meals were then dried at 40°C in an oven for 30 minutes. The final products were cooled and package.

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)	ample C(g)
Ogi flour (control)	100	68.57	55.95
DAPM 16%+ ogi		31.43	
APC 16%+ ogi			44.05
Total (g)	10	100	100

Key:

Sample A =control
Sample B = Ogi and 16% Defatted Aduwa protein meal
Sampl C =Ogi and 16% Aduwa protein concentrate

Methods

Moisture content determination.

Five grams (5g) of the sample was weighed accurately into a pre-weighed clean dry dish provided with an easily removable lid. The uncovered dish was placed with its lid open in a well-ventilated oven maintained at 103ºC for 3 hours. The dish was covered with the lid and transferred to a desiccator at room temperature to cool for 30 minutes. It was weighed immediately and the dish with the sample was placed in the oven for another 2 hours. The steps were repeated until decreases in mass between successive weighs which do not exceed 0.5 per g wet weight basis). The loss in weight was reported as the moisture content.

$$\%\ Moisture\ content\ = \frac{W1-W2}{W1-W0}\ \times 100$$

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 was weighed into a digestion tube and 15ml of concentrated tetraoxosulphate (IV) acid (H_2SO_4) was added to dissolve the sample. Kjedhal tablet was added to start up the digestion process in a fume cupboard until it gave a clear solution. Distilled water (75ml) was added to prevent it from solidifying after digestion. The tube was placed in a distilling unit and 50ml of 40% NaOH dispensed into 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 will be seen. A blank was first titrated, and the titre value was recorded (AOAC, 2010).

$$\%\, Total\ Nitrogen\ = \frac{Titre\ value \times 14.01 \times 0.47}{Weight\ of\ sample \times 100}$$

$$\%\, Protein\ = Total\ nitrogen\ \times conversion\ factor$$

$$Molecular\ weight\ of\ Nitrogen\ = 14.01$$

$$Molarity\ of\ HCl\ = 0.47$$

$$Conversion\ factor\ = 6.25$$

Ash content determination

Two grams (2g) of the sample was weighed into an empty porcelain crucible that was previously ignited and weighed. The sample was ignited over a hot plate in a fume cupboard to char (burnt and black) organic matter. The crucible was thereafter placed in the muffle furnace maintained at a temperature of 600^{o}C for 6 hr. After ashing, it was then transferred directly to a desiccator and weighed immediately (AOAC, 2010).

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

Crude fat determination

Crude fat determination was carried out using the method of AOAC (2010). The thimble was cleaned and empty weight recorded as W_1. Five (5) grams of oven dried sample was added and re-weighed as (W_2). Round bottom flask was filled up with petroleum ether up to three quarter 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 100ºC for 1 hour and later cooled in the desiccator. The sample was then weighed as (W_3).

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

Crude fiber determination

Crude fibre content of the sample was determined using the method described in AOAC (2010). Two (2) grams of sample was 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 for ashing at 600°C for 1 hour. The ashed sample was removed from the furnace and put into the desiccator to cool and later weighed (W2). The percentage crude fibre was calculated thus:

$$\%\ Crude\ fiber\ = \frac{W1\ -W2}{Weight\ of\ sample} \times 100$$

Where:

W1 = Weight of crucible and residue
W2 = Weight of final ashed sample

Carbohydrate content determination

Carbohydrate content determination was determined by difference (Ihekoronye and Ngoddy,1985)

$$\%Carbohydrate$$

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

Determination of Phytochemical properties.

Determination of alkaloids

Alkaloids was quantitatively estimated using the method of Harborne (2005). Five grams of the 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 concentrated on a water bath to one-quarter of the original volume. The extracts were then 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:

$$\text{Alkaloid content}=\frac{weight\ of\ the\ dried\ residue}{weight\ of\ the\ origial\ sample} * 100$$

Total Phenolic Content (TPC)

Total phenolic content of the sample was determined according to the Folin-Ciocalteau method of Slinkard and Singleton (1977) with some modifications by Roghini and Vijayalakshmi (2018). The sample was extracted by making a suspension of 500 mg of the sample and garlic acid in 10 ml of distilled water. The sample was vortex every 10 minutes for 1 H. The mixture was centrifuged to obtain the extract. Briefly, 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) added. The mixture was incubated for 5 min and 1 ml of 7% sodium carbonate was added. The reaction mixture was incubated for 2 H in the dark and the absorbance of the mixture was measured at 765 nm. Similarly the blank was prepared in the following manner but without the samples. The standard garlic extract was prepared in different concentrations (100, 200, 400, 600, 800 and 1000 µg/ml) to obtain the calibration

curve and the total phenolic content of the sample was extrapolated from the standard curve and expressed as mg of garlic equivalents per gram of extract.

Determination of Saponin.

The saponin content was determined according to the method of Obadoni and Ochuko (2002). One gram of the sample was mixed with 10 ml of 20 % ethanol. The sample was heated over hot water for 1 H, with continuous stirring at 55 ºC. The mixture was filtered and the residue reextracted with another 20 ml of 20 % ethyl alcohol. The combined extracts were reduced to 10 ml over a water bath at about 90 ºC. The concentrate is then transferred into a 250 ml separating funnel and 10 ml of diethyl ether is added to the extract and vigorously shaken. The aqueous layer is recovered while the diethyl ether layer is discarded. 12 ml of *n*-butanol were added and the combined *n*-butanol extract was washed twice with 10 ml of 5% sodium chloride. The remaining 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 as mg/g of extract.

Phytate Determination

Five (5 mL) of the sample was mixed and cured for 5H and filtered. Aliquot of 2500 mL of the filtrate in a conical flask was added to 5.00 mL of 0.30% ammonium thiocynate. The mixture was titrated with standard iron (III) chloride solution to a persistent brownish yellow coloration that persisted for 4 min. The amounts of phytates were calculated with the equation below (Iwuozor, 2019)

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

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

Bulk density

Five (5) gram of flour sample of the tiger nut was poured into a 100 ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g /cm^3) was calculated as weight of flour (g) divided by volume of flour (cm3). (Oladele *et al*., 2007).

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

Foam capacity (FC) and Foaming stability

FC was determined according to the method described by Adebiyi and Aluko, (2011) 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 20 mm foaming shaft on the polytron PT 3100 homogenizer (LD -5 BOSCH Switzerland). The capacity of the continuous phase to include air (FC) was determined as follows using the mean of 3 measurements.

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

Foam Stability (FS)The ability to retain air for a certain period (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

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

Water Absorption capacity (WAC)

The WAC was determined using the method of Adebiyi and Aluko, (2011) with slight modifications. Protein sample (1 g) was dispersed in 10 mL distilled water 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 water in the upper phase drained for 15 min and tube containing the protein residue was weighed again to determine amount of water retained per gram of sample.

Oil Absorption capacity (OAC)

The OAC was determined using the method of Adebiyi and Aluko, (2011) with slight modifications. Protein sample (1 g) was dispersed 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 drained for 15 min and tube containing the protein residue was weighed again to determine amount of water or oil retained per gram of sample.

Swelling index

Swelling index was determined according to the method by Olaitan *et al*., (2014). Two (2) grams of the flour sample was 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.

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

Swelling capacity

Swelling index was determined according to the method by Takashi and Sieb, (1988). One (1) grams of the sample W1 was poured into pre – weighted centrifuged tube and 10ml of

distilled water added and mixed gently with using glass stirring rod. The slurry formed was heated separately at a constant temperature of (60, 70, 80, 90 and 100 ºC) in water bath for 15 –minutes. During the heating process, continues gentle stirring is done to prevent lumping at the end of the of 15 minutes, the tubes were centrifuges at 4000xg for 10 minutes. The supernatant discarded immediately, and the tubes dried at 50oC for 30 minutes, cooled and then weighed W3. Centrifuge containing sample before adding distilled water is weighted as W

Swelling capacity $= \frac{change\ in\ volume\ of\ sample\ (ml)}{Original\ volume\ of\ sample(ml)}$ or $= \frac{\mathrm{W3-w2}}{w1}$

W_3= weight of tube + sample after centrifuge and drying

W_2 weight of tube + Sample before centrifuging

W_1 weight of sample

Emulsifying properties.

Emulsifying activity index (EAI) and emulsion stability index (ESI) were determined using the method modified by Adebiyi and Aluko (2011). Protein slurry of. 10, 25, or 50 mg/ml each were mixed with 30 ml of deionised water. This protein solution was mixed with 10 ml of sunflower vegetable oil, and the pH was adjusted to 3, 5, 7, and 9. The 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 homogenisation 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 spectrophotometer (UVIKON 930, BIO-TEK Kontron, Germany). This was used to calculate EAI and ESI using the method suggested by Pearce and

Kinsella (1978):

Emulsifying activity index EAI m2/g

$$EAI = \frac{2x2.303x\ Ao}{0.23x\text{protein weight g}}$$

Emulsion stability index ESI min

$$= \frac{A10 \times Dt}{DA}$$

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.

Least gelation concentration (LGC)

LGC was determined according to the method of Adebiyi and Aluko, (2011) with slight modification. I 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.

Determination of protein Dispersibility

Dispersibility was determined by using the method described by Kulkami et al. (1991). 10g of the samples were weighted into a 100ml measuring cylinders and water added to make up to 100ml. The set- up was stirred vigorously and allowed to stand for three hours. The volumes of settled particles were taken and subtracted from 100.

% Dispersability =100 -Volume of settled particle

Discussion

Proximate Composition of starting Aduwa protein Meals and Concentrate

The moisture content of the desert date *aduwa* meal sample DAPM (4.96%) and APC (5.31% are significantly different (p>0.05) from the control. The *Aduwa* deffated protein meal (4.86%) has significantly high fat content at (p>005) than APC (0.46%) and Ogi sample (4.83%) According to Datti et al., (2020) ,39.63% fat content have been reported on raw desert date kernel extracted using organic solvent. This result is supported by similar reports by Lohlum (2012); Sara and Mahdi (2016); Alhassan *et al.,* (2018) and Ogala *et al.,* (2018).The defatted *Aduwa* meal seed protein in this study was found to contain an appreciable amount of crude fibre (4.01%) significantly (p>0.05) higher than Aduwa protein concentrate APC (1.84%) and control (0.70%) .In this study, the percentage protein content of the *Aduwa* meal samples is significantly (p>0.05) different as sample meal are been resolved to defatted protein meal and protein concentrate. Crude protein content of Aduwa protein meal DAPM (35.67%), APC (62.23%) and control (6.36 %) respectively. The value observed in APC was significantly higher at (p>0.05) than DAPM and the control samples. The ash content of the meal sample analysed was found to be significantly different at (p>0.05) as sample meal are being resolved. Defatted *Aduwa* protein meal DAPM (15.38%) are significantly (p>0.05) higher than control (1.29%) and APC (1.23%) respectively. This result agreed with reports by Jock ,2011; Sara and Mahdi .2016; Alhassan *et al.,*2018 and Ogala *et al.,* 2018). The carbohydrate content of the Aduwa meals samples was significantly different. Aduwa protein concentrate APC (29.9%) has higher energy values significantly different at (p>0.05) than DAPM (27.11%), APC (27.88%). These values are higher than 7.48% reported by Datti et al., (2020) and these values were also higher than that reported by Sara and Mahdi (2016); Alhassan *et al.,* (2018) and Ogala *et al.,* (2018).

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

Sample	Moisture Content (%)	Fat (%)	Crude Fibre (%)	Protein (%)	Ash content (%)	Carbohydrate (%)

Control (Ogi)	2.53^{c}±0.09	4.83^{b}±0.01	0.70^{c}±0.01	6.36^{c}±0.01	1.29^{c}±0.14	84.29^{a}±0.36
DAPM	7.49^{a}±0.040	4.86^{a}±0.007	4.01^{a}±0.726	35.67^{b}±22.51	15.38^{a}±23.8	32.59^{c}±22.1
APC	6.30^{b}±0.117	0.46^{c}±0.026	1.84^{b}±0.010	62.23^{a}±0.05	1.23^{b}±00.02	27.94^{b}±0.1
	0.00	0.00	0.00	0.418	0.62	0.06

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

Key:APM= *aduwa* protein meal ,DAPM =deffated *Aduwa* protein meal, APC= *Aduwa* protein concentrate .

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

The proximate composition of enriched based Ogi is shown in table **3.** The proximate value of the enriched based ogi increased with material fortification. The percentage protein, moisture content, fat, ash, and crude fibre significantly increased compared with the control ogi sample. There exist no significant differences in protein content between control 100% maize ogi and the defatted *Aduwa* protein DAPM ($p<0.05$) and the protein content in APC – ogi sample. The Aduwa enriched ogi was found to have high crude protein content similar to that reported for its seed cake (Ibironke and Emmanuel, 2014) and soybean meal (Ahmed *et al*., 2009), leaves (Ogori rt al 2017), flower and fruit pulp (Okia *et al.,* 2013). The enriched samples also had higher protein content than the pulp as reported by Sagna *et al* (2014).The protein content in this study agreed with the value obtained from much room -ogi made sample by Gibson et al .(2017).About 50% ground nut meal inclusion with 50% ogi made product reported by Ajanaku et al .(2012) when groundnut seed were fortified with ogi showed 8.63% and 100%;100% showed 14.23% protein value, however lower than the present study results. Similarly, Femi Afolabi et al. (2018) revelated highest 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 source values obtained in Table 2 above could be due to that the starch molecules from the Ogi sample were able to occlude the conformations of protein meal and the protein concentrate moieties. Thus, the observed increase in protein content of the *Aduwa* -enriched maize ogi is arguably due to nutrients contribution from the *Aduwa* proteins samples.

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 is lower than the moisture value reported by Gibson et al. (2017) when crayfish powder was used to enrich ogi . This observation was also notice in fat content of the samples. The fat content of APC-ogi and control-ogi are significantly higher than the defatted sample (DAPM-ogi). There exist significant differences among the samples at ($p<0.05$). However, it crude fat is quite comparable with the fruit pulp as reported by (Favier *et al.*,1993; Lohlum *et al.*,2012; Ajanaku et al.,2012).

There exists significance difference between APC -ogi and ADPM-Ogi ($p<0.05$) on ash content but DAPM-ogi is higher than the control-ogi. Enrichment significantly increased ash content of ogi mix. The ash content was found to be lower than that found in *Aduwa* pulp as described by Sagna *et al* (2014). 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. Lohlum *et al* (2012).

The crude fibre content of the control and Aduwa protein concentrate are not significantly different ($p<0.05$), but lower than DAPM-Ogi .Crude fibre in *Balanites aegyptiaca or Aduwa* enriched ogi is quite significantly high ,however crude fibre is higher in defatted *Aduwa* resolved samples than the APC-ogi and control-ogi sample .Low crude fibre content in nuts could lead to constipation if excess of it is being consumed because crude fibre enhances bowel movements. The energy content through the carbohydrate values shows that the

control ogi sample significantly have (p<005) high carbohydrate value than the enriched ogi sample. The dietary requirement of high protein and low carbohydrate diets by consumers for obvious reasons, particularly for nutritional and health benefits and is necessitating the need for protein-enrichment of food products. Ogi is a popular meal among adults and commonly used as a weaning food for babies. It is however low in nutritional quality due to lack of essential amino acids, hence fortification of ogi with *Aduwa* protein meals will improve its protein quality and invariably enhanced nutritional quality.

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

sample	Protein (%)	Moisture (%)	Fat (%)	Ash (%)	Crude fibre (%)	CHO
control	6.36c±0.01	2.53c±0.09	4.83b±0.01	1.29c±0.14	0.70c±0.01	84.29a±0.36
DAPM-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
APC-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 are readings from triplicate determinations; Means followed by the same alphabetic on the column are not significantly different at p<0.05

Key: control, DAPM-ogi =defatted *Aduwa* protein meal and Ogi, APC-ogi= *Aduwa* protein concentrate and ogi,

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

The 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 in wet processing in food industry. The lower the bulk density, the higher the amount of the blend particles that can bind together leading to high energy value. In addition, higher bulk density is desirable since it helps to lower the paste thickness which is an important factor for sick child feeding. The DAPM-ogi had high bulk density significantly

compared to APC-ogi and the control-ogi and respectively. The 0.4g/g bulkiness from control-ogi sample are significantly different ($p<0.05$) with better good packaging properties however lower than APC-ogi and ADPM-ogi with good weight and space relationship. This observation could be due to the many air spaces in the control sample.

Swelling index (SI) of APC-ogi and DAPM-ogi samples were observed to be significantly the same ($p<0.05$) but differ with the control-ogi sample. The Aduwa protein concentrate APC-ogi and DAPM-ogi had less leachable biomaterials compared to the control- ogi sample. These changes could be attributed to biomaterial steps leaching during heating, this critical observation could be attributed to folded or unfolded nature of protein in APC-ogi and DAPM-ogi, binding tight to ogi free biomaterials. Swelling index of the sample is an indicator of the water absorption index of the granules during heating (**Loos *et al*., 1981**). The swelling capacity of food material confers the ability to form bulkiness when incorporated into the food system. The APC-ogi and DAPM-ogi samples when hydrated under certain thermal condition could release most bonded biomaterial with high swelling capacity, indicating that they could be better preferred as food systems, hence better samples for organoleptic mouthful.

Water absorption capacity (WAC) of the samples increased with increases in *Aduwa* material resolve. Sample APC +ogi had the highest WAC (1.44 g/ml), followed by sample ADPM +ogi C (1.35g/ml) and the control recorded the least value of WAC (1.03 g/ml). Water absorption capacity (WAC) is desirable for the improvement of organoleptic in food products. Increase in WAC in the blends might be due to the thickness of interfacial bi-layer model of protein-to-protein interaction and increases with increases in the *Aduwa* proteins owing 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. Chavan et al. (2001). According to Malamo et al. (2014)

this behaviour is attributed to the hydrophilic and hydrophobic balance of the residual amino acid in the material, polar amino acid, ionic strength, and lipids which are considerably observed in APC-ogi. The WAC of APC-ogi is higher than DAPM-ogi. The control had the least WAC content. The values obtained on WAC for DAPM-Ogi, and APC-ogi (1.35-1.44) g/m were lower than that reported by (Ajanaku et al.,2017) on crayfish ogi. This variation observed may be attributed to lipid interaction.

The oil absorption capacity (OAC) of both the control and enriched samples varied in a similar fashion like the WAC. Palatability and chewability are enhanced by OAC, this trend in water and oil absorption was observed by Ogori et al. (2019) in enriched ogi with soy peptides. The OAC increased with enrichment of Aduwa protein in ogi samples in 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 APC -ogi is significantly higher than DAPM-ogi. The results of the least gelation concentration (LGC) presented in Table 4. Indicated that sample, control -ogi had the highest LGC of (17 %). Similarly, samples DAPM-ogi and APC-ogi had the least but similar LGC of (12% and 13 %) respectively. High level value in least gelation capacity according to Osemwota et al. (2021) means less thickening capacity of enriched product which is the reason why the control sample was associated with the highest LGC (17.0%) and lowest moisture content compared to the enriched samples of (13-12%) LGC. The low LGC in DAPM-ogi and APC-ogi could be due to protein aggregation, although DAPM was not precipitated but underwent heat annealing during oil expulsion.

Foaming capacity FC

Foams are formed when protein material 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 increase volume defines foam capacity. The highest significant

value ($p<0.05$) observed was in APC-ogi (15.15%) followed by DAPM -ogi (1.0%) and the control with the least value (0.30%). The APC-ogi showed greater foaming property which could translate to high solubility observed in WAC and dispersibility index results. The high foaming index observed in APC-ogi could be due to folded/unfolded occluded ogi starch protein hydrating, while the DAPM-ogi may still be folded during step wise hydration process, limiting the protein -protein interaction needed to form interfacial membrane for foam promotion .Osemwota et al. (2021)

Percentage Dispersibility

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

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	$0.40^{c}\pm0.00$	$0.16^{a}\pm0.00$	$1.03^{b}\pm0.01$	$0.39^{c}\pm0.01$	$0.30^{c}\pm0.00$	$17.0^{a}\pm0.00$	$76.00^{c}\pm0.00$
DAPM+Ogi	$\mathbf{0.85^{a}}\pm0.07$	$0.08^{b}\pm0.00$	$1.35^{b}\pm0.00$	$0.61^{b}\pm0.00$	$1.00^{b}\pm0.00$	$13.0^{b}\pm0.00$	$76.50^{b}\pm0.71$
APC+Ogi	$0.53^{b}\pm0.04$	$0.08^{b}\pm0.00$	$1.44^{a}\pm0.20$	$1.58^{a}\pm0.20$	$15.15^{a}\pm21.0$	$\mathbf{12.0^{c}}\pm0.01$	$78.00^{a}\pm0.00$

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

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

Phytochemical screening of enriched *Aduwa* ogi reveals the presence of alkaloids, total Phenol, tannins, Saponins and phytate. Alkaloid content observed in this study is higher than that in seeds of *Daniella oliveri* and *Olax subscorpoidea* (Otori and Mann, 2014) and *Balanites aegyptiaca* flower (Umar *et al*., 2014). Alkaloids are often non-toxic and have dramatic physiological activities hence they are widely used in medicine (Olaofe and Sanni, 1988). Lower dose of alkaloids mediates important pharmacological activities, such as analgesic, reducing blood pressure, killing tumour cells, stimulating circulation and respiration (Egbuna and Ifemeje 2015) About (0.89) % was found in the control –ogi and APC-ogi (0.99)% , however lower than in DAPM-ogi (1.01)%

Phenolic is a conjugate bioactive but varies in sample DAPM-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 ogi mix could reduce antimicrobial agents and inhibit growth of pathogens. Report by Umaru et al. (2007) 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 material were used to enrich ogi. The obtained results under this study were lower than the values reported by Ogori et al. (2019) for soaked *Balanites aegyptiaca* meal flour (2.8 mg/100 g) and roasted meal (4 mg/100 g) samples. Phenolic content has been attributed to antioxidant potentials, α-amylase and α–glycosidase enzymes inhibitory and binding abilities Umaru et al .(2007

Secondary plant metabolites known as phytochemicals are known to be important to both plants and animals but could also be harmful or show some adverse effects to animals especially when consumed in large quantities hence called anti-nutrients (Ogori et al., 2020

Tannins are a Phyto anti -nutrient substance. The tannin content in the control-ogi and APC-ogi were lower than DAPM-ogi. This variation could be attributed to processing method before inclusion enrichment. Tannin has been reported to be able to precipitate certain proteins by combining with digestive enzymes thereby making the protein unavailable for digestion (Abara, 2003).) 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 (Birk and Peri, 1980; Mohammed et al.,2002). However, they are non -poisonous to warm blooded animals. Aduwa has therapeutic ability (Gloria *et al*., 2011 but at high dose saponin could cause gastroenteritis or leaking guts which could manifest by diarrhoea and dysentery (Awe and Sodipo, 2001; Mohammed et al., 2000). The saponin content in control (0.08mg/g) and enriched sample of DAPM-ogi (0.18mg/g) and APC –ogi (0.12mg/g) has very low level of saponin but significantly different at ($p > 0.05$). According to Muhammed et al.,2002 saponin lethal dose of 1-600mg/kg has been proposed. However, the control-ogi and APC-ogi have low saponin below the threshold of lethality. This reduction could be due to protein extraction method used. Various studies have revealed saponins anti-inflammatory, anti-diabetic, anti-HIV, anti-atherosclerotic, hepatoprotective and hypolipidemic abilities (Egbuna and Ifemeje, 2015).

Phytate chelates cations like calcium ion, magnesium, and zinc ions as well as certain enzyme activity Ekpa and Sani. (2018). The phytate in enriched ogi with Aduwa protein samples reduced significantly at ($P < 0.05$). Phytate content of control-ogi (0.09) mg/g and APC –ogi (0.09 mg/g) are the same but significantly differ in DAPM-ogi (0.14 mg/g). These values are lower than the values reported for peas (601.80 to709.74 mg/100). Moisture

content reduction sample matrix has been attributed to reduction effect in phytate content Ekpa and Sani. (2018). Phytic acid intake of 4-9 mg/100 g is said to reduce iron absorption by 4 to 5 folds in human (Fergusi et al., 1993). Coincidentally, enriched ogi sample has less level of phytate hence safe for consumption.

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, DAPM-ogi =defatted *Aduwa* protein meal and Ogi, APC-ogi= *Aduwa* protein concentrate and ogi.

Sensorial Evaluation

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

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
LSD	3.15	0.00	0.00	0.00	0.00	0.00	6.66

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, DAPM-ogi =deffated *Aduwa* protein meal and Ogi, APC-ogi= *Aduwa* protein concentrate and ogi ,

Conclusion

This study concluded that enriched ogi with defatted *Aduwa* protein meal and Aduwa protein 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 .Also concluded from the result is a promising low anti - nutrients especially in APC-ogi . Thus, enriched ogi protein products from *Aduwa* proteins can find useful application in protein fortification and enrichment of food.

Authors contribution

Ogori A.F performed the experiments and analysed the results. Girgih A. T designed the experiment and analysed the data, supervised, and wrote the third draft, Eke O.M wrote the first and Abu O.J wrote the second draft of the manuscript and read and edited the manuscript

Declaration of Competing Interest

The authors declared that there is no conflict-of-interest

Availability of data and material Not applicable.

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